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CONTENTS

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HYGIENIC ASPECTS OF REGULAR DIET OF FLIGHT PERSONNEL

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[Article by I. G. Popov]

[English abstract from source] The hygienic approaches to daily meals for the flying personnel while on the ground are discussed from the historical point of view. It is indicated that the hygienic requirements for the chemical composition of the daily diet are related to the physiological norms accepted by the nutritional science in the USSR and other countries at various stages of its development. It is shown that the present-day diets for the flying personnel are of high caloric value. The basic physiological and hygienic requirements for the daily diets are given.

[Text] A proper diet is one of the most important hygienic means of preserving life, good health and high work capacity in man, whatever his occupation is.

The physiological and hygienic importance of a diet that is appropriate in all respects (or wise) increases significantly when man is exposed to various adverse environmental factors, as well as when performing intensive physical labor and mental work, particularly if it lasts for a long time. The role of quantitative sufficiency, optimum balance and adequacy of the diet to man's living conditions increases primarily when there is increased outlay of energy, plastic substances and biologically active compounds involved in metabolism and control of physiological functions. Although all people generally require the same essential nutrients, when there are qualitative metabolic changes there could be a change in the body's quantitative requirements as to some essential chemicals or other. In such situations, the role of adequate food intake and balanced levels in it of amino acids, vitamins, fat, carbohydrates, macro- and micro-elements and other essential nutrients increases, particularly with respect to those that are not synthesized in the human body.

Working conditions during preflight preparations and in flight are unusual to a large extent, strained and sometimes difficult, and they impose high demands of health status, level of physical, nervous and mental work capacity of flight personnel. The need to maintain systematically the psychophysiological status of flight personnel on a high level compels us to

devote much attention to organization, in the system of hygienic measures, of regular and appropriate nutrition with all forms of flight work. It is also necessary to implement constant medical supervision of nutrition and dynamics of alimentary status of pilots. Appropriate nutrition of flight personnel does not refer simply to regular intake of food before flights, but to a daily diet that is adequate in chemical composition of the food allowance and energy value (EV) to the daily physiological requirements of pilots during preflight ground-based preparations and performance of flights. They should adhere to a diet that best conforms to the working conditions of flight personnel. Importance must be attributed to consideration of requirements for flight safety. It should also be added that the food issued to pilots most conform to esthetic standards set by sanitary and hygienic specifications, as well as national traditions concerning gustatory qualities, appearance, etc. A diet that meets these requirements is justifiably viewed as an important element in the system of psychophysiological training of flight personnel for flights, as well as in the control of flight safety.

The matter of organizing nutrition for flight personnel encompasses a broad range of medical, technological, design and supply problems, and it requires close cooperative involvement of various specialists. The extent and scope of participations of physicians, technologists, designers, supply personnel and other specialists are, of course, different at different stages (from scientific development of diet to practical implementation of nutrition for pilots and its medical supervision).

The work of flight personnel occurs under diverse climate and geographic, as well as professional, conditions under which various situations develop, which are sometimes difficult and unique, for taking meals, particularly in the sanitary-hygienic and epidemiological respects. Even the quantitative nutrient requirements vary. For this reason, it is impossible in practice to develop a universal standard food allowance (ration) equally suitable for all variants of flight work [18].

At the present time, we can distinguish three basic types of diet for flight personnel, the specifics of which are largely determined by living and working conditions, physiological and hygienic requirements as to quality and safety of nutrition: regular diet on the ground, which includes the preflight diet; diet during long-term flights (or onboard diet), including onboard water supply; diet for emergencies, which is inseparably linked with problems of emergency water supply.

The distinctions of development and current status of preflight, onboard and emergency nutrition for flight personnel have been discussed before [42-45]. We shall discuss here questions of hygiene of regular diet of flight personnel on the ground in the aspect of historical development.

At the present time, the daily hygienically regulated diet for ground-based conditions is the basic diet for flight personnel. It is aimed primarily at preserving health of flight personnel, conditioning pilots for successful endurance of difficult and adverse flight work factors during ground-based training and particularly in flight. This type of diet is important to permit intensive mental and physical work during flights, as well as speedy

recovery of work capacity after this work. Preservation of optimum nutritional status of flight personnel, as well as their physical state, depend significantly on appropriate organization of regular meals. The modern diet of flight personnel on the ground is the result of progressive development of problems of hygiene of pilot nutrition in the course of advancement of aviation engineering, and it is based on both achievements of science in the area of nutrition and advances in aviation medicine, in particular, the practical experience gained by aviation physicians, workers in the food service and pilots themselves.

In our country, from the first years of establishment of aviation, along with other occupational and preventive aspects, much attention was devoted to providing flight personnel with optimum daily meals. It is expressly to this form of nutrition for flight personnel that aviation medicine had and continues to impose the highest physiological and hygienic requirements.

At the early stage of aviation in our country, development of organization of nutrition for flight personnel underwent several stages. In 1920-1924, flight personnel were provided with daily food allowances, which changed somewhat in composition while having the same tendency toward increase in nutritional value with improvement of the economic situation in our country after the civil war. Pilots' rations were developed with consideration of general hygienic requirements for optimum nutrition of adults engaged in physical labor. According to the data of G. A. Arutyunov, the daily food allowance for flight personnel in 1920, which was issued in airport mess halls contained 70 g protein, 42 g fat, 327 g carbohydrates with EV of 2308 kcal; the figures for 1922 were 109, 45, 521 and 3004, respectively; in 1923, 131, 67, 601 and 3631; in 1924, 166, 68, 716 and 4251. In the period from 1925 through 1930, flight personnel took meals primarily at home, being given foodstuffs to take home in accordance with the standards and the so-called Red Army ration.

The Red Army ration was the basic form of nutrition for organized groups in our country in 1920-1930. The figures cited by F. Berngof provide some idea about the nutritional value of the daily food allowances with use of these rations: They contained 71 g protein, 42 g fat, 360 g carbohydrates with EV 2184 kcal in 1918-1921; 53, 27, 337 and 1881 in 1922; 91, 55, 533 and 3100 in 1923-1924; 93, 52, 547 and 3141 in 1925-1926; 107, 54, 558 and 3243 in 1927; 108, 60, 563 and 3329 in 1928 [9-10], 22, 29]. According to the data of F. G. Krotkov and V. M. Tarkhov [20], the ration contained 134 g protein, 61 g fat, 631 g carbohydrates with 3289 kcal EV in 1929. A comparison of these data to the nutritional value of flight personnel diets listed above leads us to conclude that flight personnel began to receive an increasing number of calories with increasing amounts of the basic nutrients starting in 1922, with due consideration of the difficulty of their occupational activities.

From 1931 on, all flight personnel and aircrews received a more improved Red Army ratio as their basic daily allowance which, according to official data of that time, had the following nutritional value: 123.4 g protein, 63.6 g fat, 618.2 g carbohydrates with total of 3634 kcal (net) EV [21, 22]. This daily food allowance contained 19 food items that are traditional in Russian nutrition, including 1 kg bread (600 g rye and 400 g wheat), 250 g meat, 50 g fat (20 g animal fat and 30 g from plants), 350 g potatoes, 330 g vegetables (including 200 g cabbage), 150 g buckwheat, 35 g sugar. This permitted

organization of three appropriate meals in the pilot mess at airports or in the home. Bread, potatoes and grain were the basic sources of energy, while meat products were the source of complete protein. The food allowance had no dairy products, eggs or fruit, which made it necessary to use a special supplementary ration for flight personnel [21].

In view of the higher health requirements for flight personnel, a special dietetic ration was issued monthly to all flight personnel and crews in addition to the basic Red Army rations, in order to prevent the adverse effects of flight factors and to further improve the diet of pilots. It had the following total nutritional value: 54 g protein, 75 g fat, 464 g carbohydrates and contained 2812 kcal [21]. The assortment of items in the dietetic ration supplemented well those in the basic ration and included butter, milk, sugar, rice, flour and others (total of 13 items). The supplemental ration augmented the nutritional value of flight personnel's food allowance when working under adverse environmental and working conditions. As a result, the total caloric value of the food increased, as did the amounts of complete proteins, fat and vitamins.

In addition, on flying days, flight and technical personnel began to be issued, starting in 1931, hot breakfasts prior to morning flights, right at the airport. The energy value of such preflight breakfasts constituted a mean of 1280 kcal, with 60 g protein, 33 g fat and 175 g carbohydrates [21].*

It was necessary to introduce such special hot breakfasts because of the requirement to avoid making flights without having eaten before them. Even then, it was noted that taking off when hungry or after an inadequate preflight meal had an adverse effect on pilot tolerance to flight factors (particularly at high altitudes) and lowered the quality of performance of flight assignments, and could be instrumental in onset of emergency situations [2, 23, 37]. The specifics of organizing meals for flight personnel at that time also consisted of the fact that the basic food allowance (Red Army rations) and supplemental dietetic rations were issued ahead of time for many days and, as a rule, handed out "in kind." These ratios were usually consumed in the home, not infrequently in the system of common family meals. Under such conditions it was difficult to institute medical supervision of schedule and appropriateness of flight personnel diet, to check that they had consumed the issued food allowance entirely, particularly in the period just prior to flights. For this reason, the introduction of hot breakfasts prior to morning take-offs (at that time, they occurred the most often) guaranteed organization of adequate preflight nutrition [23]. Subsequent flying practice confirmed entirely the physiological and hygienic validity of this specific form of nutrition for flight personnel in the period of preflight preparations. The nutritional value of the hot breakfasts was sufficient to provide pilots with the most important nutrients and energy, both in the preflight period and during short-term flights.

*According to other authors [29], the dietetic ration contained 56.6 g protein, 71.4 g fat, 532 g carbohydrates and 3133 kcal; the hot breakfasts contained 64.4 g protein, 38.9 g fat, 194 g carbohydrates and 1416 kcal.

Thus, in 1931 a rather well-developed system of organizing meals for flight personnel had been introduced in aviation practice in our country.

In the same years, the first recommendations began to appear on hygiene of flight personnel nutrition. Thus, in one of the first works on hygiene of pilot nutrition, G. M. Popov, who summed up the data accumulated in practice and his own experience in providing nutrition for flying school cadets, wrote that "... the significant expenditure of energy related to flight service requires that particular attention be given to furnishing flight and aircrew personnel with appropriate nutrition with respect to both caloric value (up to 5000 kcal) and composition of foodstuffs. The food must be diversified, rich in vitamins and phosphorus, bearing in mind the burden on the nervous system" [37]. He then offers recommendations primarily on organizing pre-flight meals.

Setting hygienic standards for flight personnel in the 1930's was based on scientific advances in the area of human nutrition with consideration of actual economic possibilities. At that time, nutritional hygienists were oriented primarily toward physiological standards proposed by the well-known physiologists and hygienists C. Voit (1831-1908) and M. Rubner (1854-1932) [21, 22, 74]. The standards quoted by both authors indicated different human requirements in energy and basic nutrients, depending on the work load. According to C. Voit, the nutritional value of daily food allowances for "moderate" work were as follows: 118 g protein, 56 g fat, 500 g carbohydrate, 2748 kcal EV and for "heavy" labor, 145, 100, 500 and 3217 kcal, respectively. According to M. Rubner [21], with "moderate" work, adult requirements were as follows: 127 g protein, 52 g fat, 509 g carbohydrate, 2871 kcal EV, and with "heavy" labor, 165, 70, 565 and 3280, respectively [22, 74].

On the basis of studies pursued to determine the nutritional value of the Red Army ration, which was the basis of pilot nutrition, F. G. Krotkov and V. Tarkhov arrived at the conclusion that it coincided to a significant extent with the norms of C. Voit and M. Rubner [20-22]. It had as many calories as the norms for heavy labor, and exceeded the recommendations for moderate work in protein and fat content, coming close to the norms for heavy labor [21, 22]. In 1931, the Red Army ration, which had an even higher nutritional value, was already higher in calories than the norm of C. Voit and M. Rubner for heavy labor. Its protein and fat content was somewhat lower than the above-mentioned norm for heavy labor [21, 22].

It should be noted that, at that time, the question of physiological norm for protein in the daily food allowance was the subject of major discussion. On the basis of experience gained in World War I, C. Voit's norm for protein was submitted to particularly harsh criticism, although it had previously been considered the basic one. Thus, A. Chittenden [61, 65, 66] proved that these norms could be reduced by half without detriment to the human body. N. Hirsheld and M. Hindhede [70] went even further, believing that the protein standard could be lowered to 25-40 g/day without impairment to nitrogen balance. Taking additional studies into consideration, M. Rubner and A. Noorden [73] objected to such drastic limitation of protein in the diet. M. Rubner considered 100 g (as the optimum) permissible for adults and A. Noorden, 70-80 g/day [22, 61]. A wise solution to the problem of the

physiological norm for protein was important not only theoretically, but for reliable safeguarding of health and work capacity under diverse working conditions, particularly when there are some economic difficulties and sources of nutritional protein (particularly of animal origin) are scarce.

At the All-Union Conference of Scientists in the Field of Nutrition at the RSFSR Narkomzdrav [People's Commissariat of Health], which convened in 1930, it was recognized that the question of physiological protein norm required further in-depth investigation. Sufficient grounds to deviate significantly from the norms of C. Voit were not found, and a resolution was passed to consider 100 g protein as the standard in the food allowance for adults with moderate work, increasing it to 150 g for heavy labor. Concurrently, it was deemed mandatory to issue at least one-third of the protein in the food allowance in the form of proteins of animal origin (meat, fish, milk, eggs), since they are closer in composition to the proteins in our body than those of plant origin. With regard to fat, a standard covering a rather wide range was proposed, 60-120 g or more. It was recommended that one-third be issued in the form of animal fat (mainly butter) as good carriers of vitamins [60].

Aside from setting standards for EV of food allowances and levels in them of protein, fat and carbohydrates, in the 1930's increasing attention began to be given to so-called food supplements, i.e., vitamins. At that time, the problem of preventing scurvy as an avitaminosis disease prompted the greatest concern. The entire experience in feeding large organized groups during World War I and in the early postwar years proved that a general increase in food allowances and optimization of their composition lowered the incidence of scurvy and then eradicated it [21, 22, 29, 62]. It was already a known fact that scurvy-controlling vitamin C is contained in foods of plant origin--fresh vegetables and fruit, as well as in milk, meat, liver and kidneys. Attention was given to the great sensitivity of vitamin C to physicochemical factors, prolonged heating and long-term storage. It was suggested that these distinctions of vitamin C be taken into consideration in organizing nutrition for all occupational groups, including pilots, for whom higher health requirements were imposed [62]. In addition to scurvy, many researchers at that time also began to pay attention to another form of avitaminosis, hemeralopia (so-called night blindness [sic]), which was often observed when there was general reduction of nutrition, particularly in the spring, which responded to treatment with cod liver oil, butter and beef liver [21]. It was particularly important to prevent hemeralopia among flight personnel, since there were greater requirements of their sight. The additional dietetic ration and hot breakfasts introduced for aviation in 1931 played an important role in preventing avitaminosis among flight personnel.

At that time, flight personnel could use a special antiscurvey ration, also introduced as a supplement in 1931, which contained a considerable amount of fresh vegetables and fruit (2.1 g protein, 0.4 g fat, 29.1 carbohydrates, 143 kcal EV) when working conditions were particularly severe in climate and geographic zones that were problematic for scurvy, in order to improve their diet [21, 23, 29].

According to the conclusion of F. G. Krotkov [23-25], the system of nutrition for flight personnel introduced in 1931 proved itself well in practice as

hygienically best and adequate to the working conditions of pilots. In subsequent years, increasing attention was given to improvement of diet for flight personnel.

In 1936, a hot dinner was added, which the pilots were given at the airport, to further improve the diet of flight personnel. Hot dinners were introduced in the place of the dietetic ration issued in 1935, which contained 23 g protein, 58 g fat, 240 g carbohydrates with 1620 kcal/day [23]. The nutritional value of the hot dinners was as follows: 60 g protein, 61.1 g fat, 206.2 g carbohydrates with 1840 kcal EV [25, 58]. Hot breakfasts [or lunches] were also issued to pilots, but with a somewhat different nutritional value: 57.6 g protein, 55.8 g fat, 213.3 g carbohydrates, 1594 kcal EV [25, 58]. Thus, flight personnel could receive about 3434 kcal at the airport on flying days with their hot breakfast and dinner (118 g protein, 117 g fat, 420 g carbohydrates) [58].* The rest of their food allowance was determined by the pilots' wishes and had to be based on items contained in the Red Army rations, which were issued, as before, to flight personnel for use primarily at home.

The most widespread system of nutrition for pilots in 1936-1938 included a hot breakfast at the airport at 0700-1000 hours, dinner at the airport at 1200-1600 hours and supper at home at 1900-2000 hours [58].

Flying school cadets received a somewhat different diet because of their heavy study loads and intake of food only in the mess. Their fortified daily food allowance had the following nutritional value: 111.6 g protein, 78.6 g fat, 715.6 g carbohydrates, EV 4145 kcal/day. The nutritional value of additional dietetic allowance was: 23.6 g protein, 29.3 g fat, 220.5 g carbohydrates and 1024 kcal EV [25, 58].

Systematic investigation of all types of food allowances for flight personnel started in the mid 1930's at the Institute of Aviation Medicine imeni Academician I. P. Pavlov (founded in 1936), the first chief of which was F. G. Krotkov [47].

Summing up the knowhow gained by them, S. S. Kholin who headed research on flight personnel nutrition at the institute, formulated in 1938 the basic requirements for organizing appropriate regular nutrition for pilots as follows: complete compensation for energy expenditures, regular and proper eating schedule, appropriate chemical composition of food items [58]. In principle, these requirements did not differ from the physiological and hygienic recommendations of those times for optimum nutrition of individuals in any occupation. At the same time, it was stressed in these requirements that it was particularly important to adhere to them in organizing meals for pilots in view of the specifics of their work and higher demands of their health and work capacity. S. S. Kholin devoted attention mainly to problems of practical adaptation of general hygienic requirements to the specifics of flying work, with consideration of state of metabolism during flights.

*According to the data of other authors, pilots received 160 g protein, 123 g fat, 484 g carbohydrates and 3663 kcal [24], or 118 g protein, 117 g fat, 480 g carbohydrates and 3532 kcal [23] with their breakfast and dinner.

In developing daily food allowances, requirements as to EV were considered of first and foremost importance. At that time, S. S. Kholin and other authors were governed by the data of P. Ye. Yegorov [16] who had established that a pilot's energy expenditure during an 8-h flight constituted 3000 kcal, as well as those of I. N. Gendel'man [58] who demonstrated that a pilot's daily energy expenditure is in the range of 2725-3166 kcal/day (under favorable meteorological conditions). Making corrections for the fact that some types of food are not assimilated (10-15%), some loss during cooking, waste and leftovers, S. S. Kholin concluded that the daily EV should constitute 4200 kcal for flight personnel [58].

Even then, the opinion had been voiced that, along with the specifics of flying work determining the physical burden and related expenditure of energy, one should also take into consideration the mental stress of individuals in this profession during flights. However, the researchers did not have a suitable method to define this parameter [24, 25, 58].

Aside from EV requirements for pilots' food allowances, it was insistently recommended that their meals have an optimum proportion of protein, fat and carbohydrates, that they contain vitamins, be well-assimilated, diversified and that they have good organoleptic qualities [24, 25, 58].

Meals for flight personnel were organized on the whole in accordance with the general requirements of nutritional hygiene. Breakfast had to provide 30% of the EV and dinner 50% of the pilots' daily energy requirements [25, 58]. Caloric value and proportion of nutrients in the daily food allowance of pilots had to conform to the standards of nutritional physiology and hygiene [25, 58].

At that time, there was already inception of a differentiated approach to organizing meals on flight days and on days of preparations for them. On flight days, it was recommended that the hot breakfasts include readily assimilated items that did not elicit fermentation in the intestine: fried eggs, omelet, cottage-cheese pancakes, white bread, butter and less often meat. Food intake had to be scheduled 1-2 h before take-off. On days of preparations for flights on the ground, the diet for flight personnel had to be organized in accordance with the general rules of nutritional hygiene [25, 58].

When working on questions of diet for a special occupational group, aside from the general requirements of nutritional hygiene, one must take into consideration the distinctions of metabolism and function of digestive organs attributable to the specifics of the job. This applies fully to elaboration of occupational and preventive meals for flight personnel. However, in 1938, as conceded by the researchers themselves, metabolism of pilots during flights had not been sufficiently investigated, while interpretation of demonstrable metabolic changes elicited the greatest disagreements in aviation medicine [15]. In view of the continuous raising of flight ceiling, the influence of altitude factors on metabolism and function of the gastrointestinal tract of pilots caused the main concern.

Researchers failed to demonstrate appreciable changes in basal metabolism at low barometric pressure [15]. It was believed that the effect of low temperature at high altitudes and in the cold season is limited mainly to loss of heat in respiratory organs, provided clothing is warm enough. But if heat loss increases to 25% of total body heat loss (which could occur, according to Diringshofen [67], at an altitude of 5000 m), basal metabolism should rise.

No noticeable changes were noted in protein metabolism during brief exposure to high altitude. It is only with high degrees of anoxemia that an increase in protein breakdown was observed [1, 15]. Protein content of blood serum did not change appreciably at altitudes of up to 6 km [15, 67, 75].

The studies pursued by T. Ye. Vladimirov and other authors at altitudes of 4250-5590 m [13, 14] made it possible to discover appearance of acetone bodies in urine of mountain climbers, which was interpreted as the result of stress or disorder in protein and fat metabolism.

Blood sugar level did not change at high altitude according to some authors and rose according to others. Many authors observed significant change in tolerance to sugar load: intake of sugar per os in doses that usually elicit glucosuria did not lead to the latter at high altitudes [15]. Several authors reported that sugar had a beneficial effect when taken before ascents. On this basis, D. I. Shatenshteyn and others [14, 15, 59] recommended that sugar be increased to 250 g in the high-altitude food allowance.

In the belief that "acid prophylaxis" is desirable at high altitudes, where alkalosis occurs, N. N. Sirotinin and other researchers [48, 69] proposed that 15 g citric acid with sugar be included in the diet. For the same purpose, they recommended intake of fruit prior to high altitude flights.

It was noted that there is greater loss of fluid through the lungs at high altitudes due to dryness of inhaled air. At 5000 m, fluid loss through the lungs doubled according to data in [67], which must be taken into consideration in organizing meals and water supply for pilots [15].

It was also noted that digestive organ function at high altitudes had not been sufficiently investigated. In essence, there are data obtained from mountain climbing expeditions. Loss of appetite was reported (with particular rapidity for meat products) and longer retention of appetite for sweets [15, 59]. Some authors called attention to lower acidity of gastric juice at high altitudes; however, other researchers never did arrive at any definite conclusions [15]. According to the data of M. P. Brestkin and N. Ye. Yegorov, which were obtained from studies on dogs, inhalation of a gas mixture with low partial O_2 pressure immediately after food intake and during maximum activity of gastric glands elicited a decrease in gastric secretion [15]. These data conform, to some extent, with those obtained during flights. Thus, for high-altitude flights, it was considered expedient to take off 1.5-2 h after a meal, i.e., when maximum gastric secretion (in the case of mixed food) had already occurred [51]. For the same reason, it was recommended to take food before altitude flights in the most readily digestible form and in moderate amounts so as not to burden the digestive system [15]. With respect to motor function of the

gastrointestinal tract, Van Lier et al. [15, 67] obtained data to the effect that it is inhibited only with very high degrees of anoxemia. And, periodic activity of the fasting stomach is first to be inhibited.

The above data were not obtained during actual flights, but in pressure chambers and during mountain climbing expeditions. The results of the studies were not infrequently contradictory, often based on a relatively limited number of cases and only on animals. For this reason, introduction of the results of such investigations to practical nutrition of flight personnel encounters some serious difficulties. Some of the recommendations ensuing from the above data were more suitable for organization of meals just prior to flights or in aircraft during long-term flights. This applies primarily to the schedule for preflight meals and use of readily assimilated foods and carbohydrates in preflight and onboard meals. These recommendations apparently had no appreciable impact at that time on formation of the daily allowances for regular meals of flight personnel on the ground. This is confirmed, in particular, by the results of analyzing the recommendations of S. S. Kholin [58] concerning regular meals for pilots.

In the late 1930's, problems of organizing regular meals were further developed, particularly because of the wide practice of high-altitude flights. S. S. Kholin and G. A. Arutyunov, who headed investigations on hygiene of pilot nutrition, wrote that "... an individual exposed to low barometric pressure, hypoxia and a number of other factors during high-altitude flight must have outstanding endurance, good health and a reserve of strength" [3]. It was believed that the validated choice of items in the daily food allowance must conform strictly to the nature of flight work and that "meals for a pilot that conform only to his liking, particularly during high-altitude flights, could have adverse health consequences" [3]. It was noted that pilots must adhere to a special eating schedule with use only of recommended food items. The beneficial effect of preflight intake of meals at the work place, i.e., airport was confirmed, with respect to prevention of diseases of the gastrointestinal tract and better compensation of energy expenditures [3, 25].

G. A. Arutyunov and S. S. Kholin, who praised the achievements made in developing diets for flight personnel, deemed it necessary to voice the following conclusion in 1939: "At the present time, we still do not have sufficient scientifically validated data on questions of physiology and hygiene of nutrition for individuals engaged in flight work, but work on many of these problems has already begun"[3].

In addition to the general hygienic requirements, when elaborating meals for flight personnel the above-mentioned authors [3] offered the following recommendations: 1) the meals should fully cover energy expenditures and be instrumental in enhancing the body's resistance to high altitudes; 2) the nutrients (protein, fat, carbohydrates, vitamins, mineral salts) must be contained in the daily food allowance in amounts that cover all of the body's expenditures; 3) the meals should conform entirely to the pilot's work schedule; 4) the foodstuffs and dishes prepared with them must be readily assimilated and yield the minimum waste in the gastrointestinal tract; 5) the food should be of a high grade in both raw and prepared form; 6) the food must have a pleasant appearance,

it must be easily digested and readily assimilated; 7) the food should not cause production of large amounts of gas [3].

In defining the energy requirements of pilots, G. A. Arutyunov and S. S. Kholin [3] took into consideration both the earlier data obtained by P. Ye. Yegorov, A. P. Apollonov, I. K. Sobennikov (3000 kcal/day) and the later studies of I. N. Gendel'man (4000-4200 kcal/day) [3, 4]. The question was raised of compensating for the great nervous and mental stress, but no concrete indications on this score were provided. Moreover, it was conceded that the authors did not yet have experimentally validated data concerning energy expenditure of pilots in aviation of those times. However, it was still suggested that pilot work be assessed as being heavy and that this should be reflected in planning their nutrition [3]. It was also stressed that inflight function of the gastrointestinal tract had not been sufficiently studied [3, 51]. The increase in gas in the intestine at low barometric pressure, possibility of development of nausea, vomiting and abdominal pain at high altitude were cited as incontrovertable data. On the basis of the possibility of intensification of gastric secretion in the presence of airsickness, it was not recommended to fly on a fasting stomach [3]. V. V. Strel'tsov [51] recommended the following for high-altitude flights, on the basis of experimental data obtained primarily on dogs: 1) to take food 2-2.5 h before take-off; 2) to use food consisting of readily digested and assimilated constituents without large amounts of fat; 3) to take food that did not contain much fiber for the prevention of gas production in the intestine.

In 1939, organization of meals for flight personnel provided, as before, for issuing "in kind" foodstuffs in accordance with the standards for the Red Army rations, as well as to take hot breakfasts and dinners at the airport. F. G. Krotkov rated highly the physiological and hygienic importance of meals right at the airport, since this guaranteed the mandatory intake of food having a specific quantitative and qualitative composition before flights. The nutritional value of the Red Army ration was as follows, according to the data of F. G. Krotkov [25]: 116.5 g protein, 75.8 g fat, 620 g carbohydrates and 3745 kcal/day EV. When traveling beyond the Arctic Circle, an additional arctic ration was issued: 14.8 g protein, 50.2 g fat, 30.1 g carbohydrates, EV 649 kcal/day. Flying school cadets received the following daily food allowance: 136 g protein, 108 g fat, 936 g carbohydrates and EV 5400 kcal.

Hot breakfasts had the following nutritional value: 58 g protein, 56 g fat, 213 g carbohydrates and 1594 kcal EV; dinners--60 g protein, 60 g fat, 206 g carbohydrates, 1840 kcal EV. The assortment of food items for breakfasts and dinners made it possible to prepare dishes for 10 days listed on a menu folder (over 30 entries). The breakfasts and dinners were quite similar in nutritional value.

The nutritional value of breakfasts and dinners was sufficient to meet the pilots' requirements in the basic nutrients during the work day. F. G. Krotkov believed that "one could hardly classify flying as a heavy form of physical labor in absolute expenditure of energy" [25]. He characterized the work of pilots and navigators as containing mainly elements of static and nervous-mental

tension. He attributed the lack of sufficiently validated experimental data concerning the energy balance in pilots to methodological difficulties. He also stressed that one could only barely validate the nutritional value of flight personnel diets with bioenergetic parameters, which characterize only the quantitative aspect of metabolism.

In that period, work on problems of flight personnel nutrition, as well as nutrition for other occupational groups, was strongly influenced by recommendations of the Expert Commission for Hygiene of the League of Nations which had proposed, in 1933-1936, new physiological standards of nutrition. According to the latter, adult requirements for an individual who did not perform any professional or other muscular work constitute about 2400 kcal/day in a temperate climate. For individuals engaged in physical labor, there had to be a supplement (in kcal/day): 75 with light work, 75-100 with moderate, 150-300 with intensive and 300 or more with very intensive labor. Protein requirement is estimated on the basis of the minimal norm of 1 g/kg body weight. Some of the protein had to be of animal origin. It was recommended to have fat in the diet, but its amount was not standardized due to insufficient investigation of lipid metabolism. Primarily fats containing vitamins A and D were recommended. Special importance was attributed to inclusion in the diet of so-called protective agents containing complete proteins, vitamins and mineral salts. They included dairy products, eggs, vegetables, fruit, meat and fish. Sugar, bread without bran, polished rice and refined fat were among the foods with adequate caloric value but relatively low protective function [25]. Taking these recommendations into consideration, in the United States, for example, daily requirements for an individual weighing about 70 kg were set at 2950 kcal (100 g protein, 50 g fat, 525 g carbohydrates) with a light physical load, 3675 kcal (125 g protein 75 g fat, 625 g carbohydrates) with a moderate one and 4300 kcal (150 g protein, 100 g fat, 700 g carbohydrates) with heavy physical labor [25].

The next important stage in development of regular diet for flight personnel was the introduction in 1941 of the single special daily standard. As reported by G. A. Arutyunov, who headed this work, the need for a single daily food allowance for flight personnel and organization on its basis of centralized regular meals for them in airport messes was due to a significant extent to the fact that flights began to take place both in the daytime and at night, yet pilots continued to receive only hot breakfasts and dinners. The new organization of nutrition made it possible to reliably provide flight personnel with regular nutrition, which also included a preflight meal, at any time of day. Introduction of a single daily standard imparted a more finished appearance to the entire organization of regular meals for flight personnel, and it had definite occupational-preventive orientation. The nutritional value of a single daily meal provided, according to G. A. Arutyunov's data, daily intake by pilots of 148 g protein, 92 g fat, 644 g carbohydrates with EV 4101 kcal [5, 49].

V. A. Spasskiy concluded [49] that organization of meals for flight personnel in this period continued to be based on the general theses of the science of nutrition and data in aviation physiology. In developing nutritional standards for pilots, he deemed it possible to use as base data the recommendations of C. Voit, M. Rubner and others about any of the widespread average physiological norms of those days.

The main requirement consisted of providing a quantitatively adequate diet and compensating for all energy and plastic substance expenditures of pilots. In a study of energy expenditures of flight personnel in 1940, G. A. Arutyunov, A. F. Legun and other authors established that they are in the range of 2400-2700 kcal/day. Considering the additional expenditure of energy with possible complication of working conditions, they proposed a standard of 3500 kcal/day for flight personnel [49].

With respect to protein, it was recommended that pilots take in at least 80-100 g/day, which conformed to the standards of most authors.

With the start of the Great Patriotic War, new norms were introduced for the routine nutrition of flight personnel (in September 1941), which called for four types of daily food allowances, depending on the nature of flying work. The daily food allowances with the highest amounts of nutrients were for the crews of aircraft in the field forces; according to G. A. Arutyunov, they contained 170 g protein, 126 g fat and 747 g carbohydrates, with EV 4932 kcal [73].

In the early postwar years, the regular diet of flight personnel in propeller-engine aviation was organized on the basis of using the above-mentioned daily food allowance. The basic factors that must taken into consideration, according to G. A. Arutyunov, when organizing meals for flight personnel in 1948 were the shortage of oxygen, low atmospheric pressure and low temperatures [5]. In his opinion, use of foods with a succagogue effect is required to alter the function of the gastrointestinal tract, in particular, to inhibit secretory and motor activity. Attention was devoted to change in nitrogen, carbohydrate and lipid metabolism in the presence of hypoxia. There were data to the effect that pilots' tolerance to altitude is lowered when protein content in the preflight meal exceeds 10-15% of total caloric value. An increase in blood lipid content and appearance of acetone bodies in urine in the presence of hypoxia were indicative of change in lipid metabolism. For this reason, it was recommended to take food rich in carbohydrates, rather than fat, prior to high-altitude flights, since the capacity to oxidize carbohydrates does not change or is increased under hypoxic conditions. It was assumed that a store of well-assimilated carbohydrates enhances tolerance to altitude. Increasing importance was attributed to vitamin content of food, since it had been established that vitamin A, B and C requirements are higher under hypoxic conditions. For this reason, it was suggested that vitamins be added to food in doses considerably greater than the usual physiological norm prior to high-altitude flights [5].

G. A. Arutyunov devoted much attention to organization of a proper eating schedule. The following was the most popular distribution of daily foods: breakfast 25-30% of total daily caloric intake, lunch 10-15%, dinner 40-50%, supper 15-20% [5].

In the early 1950's, because of the intensive development of jet aviation, more attention was again given to development of preventive agents to protect pilots against adverse flight factors. A daily food allowance with higher nutritional value was intorduced in 1951 specially for jet aviation crews. However, it was introduced without deep enough prior scientific preparation, and it was known to be excessive which was soon confirmed by experience. If

we compare its nutritional value to the "Physiological standard requirements for adults as to proteins, fat, carbohydrates, vitamins and minerals" [19, 46] developed by the Institute of Nutrition, USSR Academy of Medical Sciences, under the supervision of O. P. Molchanova and recommended by the USSR Ministry of Health in 1951 (standards of VGSI [All-Union State Sanitary Inspectorate] of the USSR Ministry of Health--1951), it is not difficult to see that the food allowance of jet aviation aircrews exceeded the physiological standards for all occupational population groups. In particular, the food allowance of pilots in 1951 was more nourishing than the recommendations for nutritional value of allowances for individuals engaged in heavy unmechanized labor (4th occupational group): 140-160 g protein, 130-150 g fat, 550-650 g carbohydrates with EV 4000-5000 kcal/day [19, 31-32, 46]. G. A. Arutyunov concluded that in this period the energy expenditures of pilots referable to different occupations were in the range of 3200-4200 kcal/day.* Energy expenditures for flight crews operating jet and propeller-engine aircraft did not differ appreciably. Moreover, G. A. Arutyunov and other authors referred flight personnel to the 2d occupational group in the above-mentioned physiological standards according to bioenergetic parameters (3200-3500 kcal/day). Investigation of actual food intake revealed that pilots consumed food totaling no more than 4268-4700 kcal, i.e., they regularly failed to make full use of the daily meals issued. That the meals were somewhat excessive was confirmed by the presence of uneaten food and a tendency toward weight gain by some pilots.

In order to provide aircrews with meals that are more consistent with their requirements and with consideration of experience with the food allowances adopted in 1951, new, improved standards were developed for flight personnel nutrition. Starting in 1958, the crews of all aircraft began to use the same daily food allowance in their regular nutrition.

Thus, the nutritional value of the daily food allowances for jet aircraft crews diminished somewhat in 1958, although it remained adequate to satisfy requirements in basic nutrients, even in the case of heavy unmechanized labor (in accordance with the physiological standards of 1951).

The basic daily food allowance for flight personnel consisted of 35 items of food and seasoning, which made it possible to provide them with diversified, tasty and nourishing food four times a day. An additional food allowance consisted of four items (egg, chocolate, canned fruit, fresh fruit or fruit juices), which enriched even more and diversified the basic daily food allowance [17]. It could also be used for supplemental nutrition in intervals between tense flights in jet aircraft.

According to G. A. Arutyunov, the nutritional standards for flight personnel were prepared in 1958 with more objective consideration of energy expenditures and nutritional requirements of pilots. They also took into consideration age, occupation and living factors. The above-mentioned "Physiological standards of adult nutritional requirements," which were developed at the Institute of Nutrition in 1951, served as the scientific basis for setting hygienic standards for flight personnel nutrition. In 1959, F. G. Krotkov stressed that nutrition of flight personnel must, first of all, conform to the requirements for appropriate nutrition of people [26].

*Other authors cite somewhat different figures for pilots' energy expenditures: 3500-3700 kcal [50] and 3000-3500 kcal [30].

According to the estimates of several authors [8, 17, 18, 40], the daily food allowances introduced in 1958 could more than cover the actual daily energy expenditures of pilots under the most diverse working conditions.

The share of protein in total daily caloric value of food allowances was 13%, which conformed to the physiological standards of 1951. Amino acid content in the diet was assessed as normal by G. A. Arutyunov, as compared to the minimum standards for adults. At the same time, the question was raised of investigating their role to enhance pilot work capacity because of some of the specific effects of flight factors on amino acid requirements. The food allowance as a whole had to meet the pilots' protein requirements, as confirmed by excretion in urine of 300-500 mg/day amino nitrogen (nitrogen of free amino acids).

Fat content in the flight food allowance exceeded somewhat the physiological norm, reaching 32% of total daily calories [18, 27]. Considering the biological role of unsaturated essential fatty acids, the daily food allowance included also plant oil in the form of sunflower seed oil.

Carbohydrates constituted about 55% of total calories in the regular diet of pilots [27]. Readily assimilated monosaccharides and disaccharides were prominent among them.

Physiological-hygienic studies and dynamic observation of health status, physical development and work capacity of flight personnel, which were pursued in the 1960's-1970's, led to the conclusion that the existing single standard for regular nutrition is not only adequate to meet the energy requirements of pilots, but has substantial reserves [17, 18]. For this reason, the daily food allowances introduced in 1958 did not undergo substantial change in subsequent years. Some modification was made, however, in composition of vitamins issued with the daily meals. The product, Hexavit, which contains vitamins A (retinol acetate), B_1, B_2, B_6, C and PP began to be used in 1968 [18]. Inclusion of vitamin B_6 in the diet was attributable to the results of studies that warranted consideration of pyridoxine as a means of preventing airsickness [18, 28, 55, 56, 64, 71].

A comparison of the nutritional value of contemporary daily food allowances for flight personnel to the physiological standards for adult energy and nutrient requirements, which were developed by the Institute of Nutrition, USSR Academy of Medical Sciences, in 1968 under the guidance of A. A. Pokrovskiy [33, 35] and then, in 1982, under the supervision of V. A. Shternikov [34], confirmed the conclusion that they were adequate in both quantity and quality.

According to the EV, the daily food allowances for flight personnel according to the 1968 physiological standards of the Institute of Nutrition, USSR Academy of Medical Sciences, exceeded somewhat the energy requirements of individuals in the 4th occupational group, which includes workers engaged in mechanized or partially mechanized heavy or moderate labor with energy expenditure of up to 4200 kcal/day at the age of 18-40 years and 3800 kcal/day at 40-60 years. The diet of pilots is rather similar in caloric value to the one recommended for individuals in the "additional occupational group," which

included workers who were regularly engaged in very heavy manual labor (diggers, loaders, etc.) with energy expenditure of 4500 kcal/day or more [33, 35].

If we compare the above to the physiological standards for 1982, we shall find that the daily food allowances for flight personnel exceed in EV the energy requirements for individuals in the 5th cccupational group, which includes those engaged in particularly heavy physical labor (miners, steel workers, diggers, stone masons, loaders, etc.). For those in the 5th occupational group, daily energy requirements have been set in the following ranges: 4300 kcal for individuals 18-29 years of age, 4100 for those 30-39 years old and 3900 kcal for those 40-50 years old [34].

The amounts of basic nutrients in the daily food allowance for flight personnel, for which standards are set in the 1982 recommendations on nutrition (protein, fat, carbohydrates, vitamins A, B_1, B_2, B_6, C, calcium, phosphorus and iron) also exceed the physiological standard requirements for individuals in the 5th occupational group and on the whole conform to the formula for a balanced diet [36].

The above analysis enables us to conclude that use of the contemporary daily food allowances for regular meals of flight personnel, provided there is adherence to an appropriate eating schedule, virtually precludes the possibility of development of quantitative or qualitative energy or basic nutrient deficiency. For this reason, the daily food allowances for pilots are justifiably deemed to meet their energy and nutrient requirements under the most diverse working conditions, ranging from mental work to the heaviest physical labor involving a heavy muscular load or high nervous-mental stress [17, 18].

At the same time, the presence of a significant reserve of nutrients in the daily food allowance for pilots requires stricter medical monitoring of daily intake of food and its nutritional value, i.e., actual nutrition, as well as dynamics of alimentary status of pilots. There is an urgent need for pilots themselves to be more aware of their regular nutrition and physical condition [11, 17, 18, 41].

Constant use of the existing daily food allowances in full, regardless of daily expenditure of energy, should lead to systematic overeating, at least for some pilots and, consequently, could affect health and work capacity [11, 17, 18, 38-41, 57].

In the opinion of several foreign authors, the regular meals of flight personnel and aircrews essentially differ very insignificantly in requirements from the standard recommended diet, not counting some special flights [57, 63]. For this reason, when elaborating nutritional standards abroad for flight personnel, the national physiological dietary standards are generally used as the basis. For example, the "Recommended Dietary Allowances" developed by the Food and Nutrition Board of the National Research Council were used in the United States [57, 63, 68-69, 72]. Subsequently, the same guidelines served as the basis for developing diets for cosmonauts [63, 72]. In a number of instances, it is recommended to correct the general hygienic nutritional requirements and single standards for flight personnel with consideration of health status and physical development of pilots. In particular, all individual factors,

including blood cholesterol and triglyceride levels, arterial pressure, heredity, history, weight, physical status, diet and smoking, must be taken into consideration by aviation physicians in order to prevent cardiovascular disease [57, 63].

Aside from the quantitative aspect of nutrition, in a number of instances it is necessary to optimize the existing method of supplementing the diet with multiple vitamin products. Regular intake of these products requires good self-discipline on the part of pilots and effective medical supervision. For this reason, the possibility of using foodstuffs and prepared dishes with vitamin supplements in the diet of pilots is attractive.

The basic physiological and hygienic nutritional requirements of the modern daily meals of flight personnel can be defined as follows:

1) The caloric value of daily allowances must cover entirely the energy expenditures, while the nutrients must conform to the body's requirements in different climate and geographic zones.

2) Nutrients must be contained in the appropriately balanced proportion in the main meals (breakfast, dinner, supper).

3) Mealtime schedule and distribution of the daily food allowance must conform to the schedule for the day and nature of flight.

4) Daily food allowances must consist only of items that are specially recommended in flight personnel dietary standards.

5) Substitution of recommended items must be made in exceptional cases due to climate and geographic distinctions of metabolism and diet, sanitary and culinary considerations, with adherence to hygienically validated rules for appropriate substitution of food items.

6) Foodstuffs and prepared dishes should be selected with consideration of effects of adverse flight factors and functional distinctions of the gastrointestinal tract during flights.

7) Prepared foods must have good flavor, they must be diversified enough and safe from the standpoint of sanitation and epidemiology.

Considering that the single daily food allowances do not conform entirely to individual energy and nutrient requirements of all categories of pilots, let alone for different types of professional activities, it is deemed promising to develop recommendations for dynamic correction of the standard allowance to apply to the individual requirements of pilots. Improvement of daily nutrition for individuals with deviations in nutritional status, health and work capacity merits special attention. This, of course, will require much additional work on the part of aviation physicians with respect to in-depth analysis of dynamics of physical development and metabolism of pilots.

Analysis of literature sources indicates that questions of enhancement of general physical and mental work capacity, as well as efficiency of different organs and physiological systems of pilots during preparations on the ground

and during flights by means of using some nutrients or other in amounts exceeding the recommended physiological standards, as well as in a different balance, have not yet gained appropriate development and, as before, require the attention of researchers.

In conclusion, it should be noted that the entire history of development of regular nutrition for flight personnel is indicative of the inseparable link between the bases of this form of pilot nutrition and general physiological-hygienic nutritional requirements for the healthy, able-bodied population, the process of improvement of physiological dietary standards for man that are based on fundamental research in the field of physiology, biochemistry and hygiene of nutrition.

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EXPERIMENTAL AND GENERAL THEORETICAL RESEARCH

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METABOLIC DISTINCTIONS OF HUMAN RED BLOOD DURING LONG-TERM SPACEFLIGHTS

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[English abstract from source] Before and after the 150-day Salyut-7 flight the crewmembers were examined for their red blood metabolism, viz: major metabolic pathways (glycolytic and pentosophosphate), erythrocyte resistance, membrane permeability and lipid peroxidation rate. The resulting data indicate that the metabolic and membrane changes were not pathological and can be classified as adaptive.

[Text] Previous studies of the effect of long-term weightlessness on metabolism of red blood corpuscles revealed some changes in energy metabolism of erythrocytes. The main change was a decline of ATP concentration in the presence of normal or increased glycolytic process [5]. At the same time, after completion of 63- and 140-day missions, there was a tendency toward decline of ATP with concurrent decrease in glycolytic activity [6, 9], which most probably reflected the functional state of the entire body, as characterized by low energy metabolism in flight. The decline of ATP level we demonstrated, with concurrent intensification of the energy-producing process, may be indicative of increase in rate of ATP-consuming processes, in particular intensification of transport ATPases due to possible changes on the membrane level. In addition, we cannot rule out the possibility of reduction of the nucleotide pool due to the general catabolic orientation of processes in the body. In view of the foregoing, we undertook an expanded investigation in which, in addition to previously studied parameters of erythrocyte metabolism [levels of ATP and 2,3-diphosphoglycerate (2,3-DPG), intensity of glycolysis, level of reduced glutathione (GSH), activity of lactate dehydrogenase (LDH) and glucose-6-phosphate dehydrogenase (G-6-PD)], we determined such parameters as rate of glucose uptake, which characterizes the intensity of basic and erythrocyte pathways (Embden-Meyerhof and pentose phosphate), level of oxidized form of glutathione (GSSG) and glucose-6-phosphate (G-6-P), the initial substrate of the pentose-phosphate pathway, the latter being responsible for redox reactions in cells, permeability of the erythrocyte membrane (according to K^+ release into external medium), cell sensitivity to oxidative and mechanical factors, intensity of processes of lipid peroxidation (LPO) and spectrum of fatty acids--parameters characterizing the state of the membrane.

To determine these parameters, we examined cosmonauts before and after completing a 150-day space mission aboard the Salyut-7 orbital station.

Methods

We examined erythrocytes isolated from peripheral blood and eluted twice in saline (PSS). The parameters in question were assayed in an erythrocyte suspension before and after its incubation in plasma and PSS. Concentration of ATP, glucose, G-6-P, oxidized and reduced glutathione, intensity of glycolysis (from lactate increment), activity of LDH and G-6-PD were determined by spectrophotometric methods [7]. Erythrocyte membrane permeability was tested according to rate of K^+ discharge (in mM/ℓ erythrocytes/h) into the external medium. The measurements were made in a heat-controlled well (37°C) with a valinomycin electrode. We assessed red cell resistance according to effects on them of a mechanical load and oxidation stress. The mechanical load was generated with a peristaltic pump which compressed the erythrocyte suspension at the rate of 2 mℓ/min through a silicon tube with wire clamp that produced pressure of 2.5-3.5 atm. Rate of hemolysis was recorded according to change in dissipation of light by the erythrocyte suspension (wavelength 1000 nm), and it was expressed as percentage per minute.

Oxidation stress was produced by addition of tret-butyl hydroperoxide (TBHP) to the erythrocyte suspension at the rate of 5 mm/ℓ erythrocytes/h. We assayed in the erythrocyte suspension the oxidized and reduced forms of glutathione, rate of release of K^+ and concentration of ATP. Lipids were isolated from the erythrocyte membrane by the method of Bligh and Dyer [8]. Primary (hydroperoxides) and secondary LPO products were assayed by the polarographic method with a mercury-drop electrode [3].

Examination of fatty acid composition of erythrocyte membrane lipids was performed using a Tsvet-110 chromatograph with ionization-flame detector [1]. Methyl ethers of fatty acids of total lipids were recovered with tetramethyl ammonium hydroxide and methyl iodide [2].

Results and Discussion

The study of parameters of the energy process in red cells revealed a tendency toward decline of its intensity on the 1st postflight day, as manifested by reduced rate of glucose uptake (V_{gluc}), which was found in one of the cosmonauts, as well as some decrease in lactate increment (V_{lact}) during incubation of erythrocytes in plasma and saline. At this same time, we found a decrease in ATP concentration, both in samples fixed immediately after drawing blood and during the period of incubation of the erythrocyte suspension (Table 1).

Examination of the pentose-phosphate pathway of glucose oxidation, the basic role of which was to maintain redox processes in cells, revealed changes manifested by decrease in G-6-P (Table 2). This could be due to its increased oxidation in the pentose-phosphate pathway. The intensification of G-6-PD activity that we demonstrated is in favor of this assumption. In all likelihood, these changes were directed toward maintaining redox processes in cells and, first of all, the amount of reduced glutathione, the concentration of which was low,

Table 1. Characteristics of energy process in erythrocytes before and after flight

Cosmonaut	V_{gluc}, μM/g Hb/h*			V_{lact}, μM/g Hb/h					2,3-DPG concentration, μM/g Hb		
	preflight (PRF)	postflight (PF) day		PRF	postflight day				PRF	PF day	
		1	7		1		7			1	7
				PSS	plasma	PSS	plasma	PSS			
1	4,30	4,36	3,83	8,61	6,30	7,33	7,90	7,25	13,40	16,22	—
2	3,20	2,49	3,05	8,88	6,45	5,40	6,42	5,90	14,22	16,12	13,86

ATP concentration, μM/g Hb*						LDH activity, μM NAD•H_2/g Hb		
preflight		postflight day					PF day	
		1		7		PRF	1	7
before incubation (BI)	incubation (I)	BI	I	BI	I			
4,90	5,06	3,25	5,30	4,92	4,50	25,82	31,03	—
5,89	5,45	3,08	4,73	4,80	5,22	25,57	30,63	20,80

Note: Here and in Tables 2 and 4, a dash signifies that tests were not made. Asterisk indicates incubation in saline. Here and in Tables 2 and 3: PRF--preflight, PF--postflight, BI--before incubation.

Table 2. Characteristics of redox processes in human erythrocytes before and after flight

Cosmonaut	G-6-P, μM/g Hb				G-6-PD activity, μM NADP•H_2/g Hb		
	PRF	postflight day			preflight	PF day	
		1		7		1	7
	PSS	plasma	PSS	plasma PSS			
1	191	117	130	144 97	4,12	5,19	3,13
2	117	44	99	123 138	3,39	5,95	

GSH, μM/g Hb			GSSG, M/g Hb/h						
	PF day			postflight day					
				1			7		
PRF	1	7	PRF	BI	plasma	PSS	BI	plasma	PSS
6,91	5,48	6,10	20	10	27	60	3	45	120
9,62	8,70	6,69	26	33	28	42	0	52	102

particularly on the 1st day after landing, which can probably be attributed to its (GSH) diminished synthesis. This is indicated by the data obtained from determination of the plasma pool of free amino acids, which were indicative of the catabolic orientation of processes in the body after long-term exposure to

weightlessness [4]. In addition, we cannot rule out the possibility of decrease in amount of reduced glutathione due to some intensification of oxidative processes. This is indicated by the increase in concentration of oxidized glutathione when the erythrocyte suspension is incubated in plasma and PSS. The rise of this parameter is particularly marked in cosmonaut 1 on the 7th postlanding day. At the same time, some activation of oxidative processes is not significant and does not elicit impairment of cell resistance. This is confirmed by data obtained from examination of functional state of membranes (Table 3), and it indicates that oxidation stress (delivery of tret-butyl hydroperoxide into the sample) does not elicit substantial changes in level of oxidized glutathione, as compared to the physiological norm.

Table 3. Characteristics of functional state of erythrocyte membranes before and after flight

Cosmonaut	Rate of K^+ discharge, mM/ℓ red cells/h					GSSG concentration, mM/ℓ red cells with TBHP			Hemolysis rate, %/min with mechanical load		
	PRF	postflight day				pre-flight	PF day		pre-flight	PF day	
		1		7			1	7		1	7
	PSS	plasma	PSS	plasma	PSS						
1	2,0	1,2	1,5	0,7	1,2	300	270	350	1,2	1,4	2,6
2	1,2	0,7	1,1	1,1	1,2	350	410	450	1,2	0,9	1,8

Table 4. Total lipid fatty acid levels and state of LPO in human erythrocyte membranes before and after spaceflight

Substance examined	Physiological norm	Cosmonaut 1			Cosmonaut 2		
		pre-flight	postflt. day		pre-flight	postflight day	
			1	7		1	7
Fatty acids (rel.%):							
myristic (14:0)	1,2±0,1	—	1,6	0,9	—	0,8	0,7
palmitic (16:0)	23,8±0,4	—	27,3	19,6	—	30,5	23,7
palmitoleic (16:1)	3,9±0,3	—	4,9	2,4	—	4,9	5,2
hexadecadienoic (16:2)	1,6±0,2	—	2,9	2,0	—	1,7	1,9
stearic (18:0)	20,7±0,7	—	31,4	25,3	—	29,8	21,3
oleic (18:1)	23,5±0,7	—	27,7	26,1	—	27,2	22,8
linoleic (18:2)	10,5±0,4	—	1,9	7,6	—	2,4	7,3
linolenic (18:3)	1,9±0,3	—	1,9	0,8	—	2,4	2,8
eicosatrienoic (20:3)	3,8±0,3	—	—	3,4	—	—	5,1
arachidonic (20:4)	10,3±1,0	—	—	11,4	—	—	6,8
LPO products, nA/mg lipids:							
hydroperoxides	21,4±0,4	46,87	20,59	—	24,1	22,7	27,55
end products	48,6±4,6	131,70	48,90	—	57,6	42,61	80,54

Measurement of rate of discharge of K^+ into the external medium failed to demonstrate differences in the two cosmonauts, as compared to baseline studies and the physiological norm, which is indicative of absence of impairment of erythrocyte membrane permeability. Examination of the rate of hemolysis with use of a mechanical load also failed to demonstrate appreciable changes in red cell resistance in cosmonauts and donors. Data on the state of LPO in erythrocyte membranes (Table 4) are also indicative of absence of significant activation of oxidative processes in red blood cells. Thus, on L+1 there was a decline of hydroperoxides and secondary products of LPO. At the same time, both cosmonauts presented a noticeable decrease in levels of polyunsaturated fatty acids--decline of linoleic ($C_{18:2}$) and absence of eicosatrienoic ($C_{20:3}$) and arachidonic ($C_{20:4}$) acids (see Table 4). The increase in polyunsaturated fatty acids on L+7 was associated with increased intensity of lipoperoxidation processes, and there was some increase in hydroperoxide content with concurrent elevation to double the level of secondary products.

Thus, the results, which are tentative by virtue of the small number of cases, are indicative of absence of pathological orientation of the demonstrated metabolic changes in red blood cells and disturbances in functional state of their membranes. The noted changes in parameters of erythrocyte metabolism are apparently adaptive and attributable to regulatory reactions aimed at maintaining structural and functional integrity of cells.

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HUMAN BODY BIOMECHANICS AND MOVEMENTS AFTER 120-DAY ANTIORTHOSTATIC HYPOKINESIA

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[Article by V. M. Zatsiorskiy, M. G. Sirota, B. I. Prilutskiy, L. M. Raytsin, V. N. Seluyanov and L. G. Chugunova]

[English abstract from source] This paper presents data on body parameters (weight and circumference) and walking biomechanics after 120-day head-down tilt. The exposure leads to changes primarily in the antigravitational muscles. They are assumed to be caused by relative changes in the fat and muscle components. Head-down tilt also produces changes in the kinematic parameters of the walking process, the shape of support reactions, and losses in the cost-efficiency of the walking process.

[Text] Hypokinesia is a generally recognized model for investigation of the effects of weightlessness. Precise quantitative evaluation of changes that occur under the effect of antiorthostatic hypokinesia (AOH) is an important part of studies in the field of space biology and medicine. One of the important results of the effect of weightlessness simulated with AOH is the change in weight of segments of the human body [4], which can occur due to redistribution of fluid or alteration of relationship between elements of the body, in particular, fatty and muscle tissue. Previously obtained data [4] require further verification and definition. In addition, the change in nature of human movements after exposure to AOH is of interest.

Our objective here was to record changes in anthropometric and inertial mass characteristics (IMC) of the human body, as well as biomechanics of walking, which occur under the effect of AOH.

Methods

This study was conducted on 6 male subjects 31-45 years of age (weight 68-91 kg, height 164-179 cm). IMC were measured three times: a few days before the start of the study (baseline), on the 3d day after 120-day hypokinesia and after a 2-week recovery period, while walking was studied twice, only after AOH.

Anthropometric measurements were made by the standard system of V. V. Bunak [1]. In order to determine weight and moments of inertia of body segments, we

used a radioisotope method [2]. Amounts of muscle, fat and bone tissue were calculated on the basis of anthropometric data, while the data from scanning on a radioisotope unit were used to determine mass, moments and radii of inertia of 10 segments: head of the humerus, forearm, hand, thigh, lower leg, foot, upper, middle and lower segments of the trunk.

The first walking test (3d day after AOH) involved having the subjects walk a 15-m lane with 2 strain-measuring platforms. We recorded static reactions, mean walking speed (using a photodiode device) and step length (according to trace left on lane). The subjects walked at an arbitrary speed, depending on how they felt. The test was repeated after a 2-week recovery period, but this time with a wider range of speeds (from 0.975 to 2.146 m/s). Each subject had to travel over the lane at different speeds 5-6 times.

External mechanical function was calculated from the horizontal, longitudinal and vertical projections of vectors and velocities of displacement of general center of mass (GCM) [5]. Velocities and amplitude of displacements were determined by integration of static reaction. Horizontal and vertical fractions of kinetic energy (E_h and E_v), potential energy (E_p) of GCM and their sum (E_t) were calculated from the horizontal and vertical velocities and vertical displacement of GCM, respectively. Then, adding up all of the positive increments of different types of energy we obtained estimates of different fractions of external mechanical work: $W_h = \Sigma\Delta E_h$ for increase in horizontal velocity of GCM, $W_v = \Sigma\Delta E_v$ for increase in vertical velocity of GCM, $W_e = \Sigma\Delta E_e$ for elevation of GCM, $W_t = \Sigma\Delta E_t$ for total external mechanical work performed in walking. The calculated parameters of mechanical work were scaled to the unit of the subject's body weight and unit of distance he traveled in a walking cycle.

The degree of recuperation of energy was determined using the recuperation coefficient [6]:

$$R = \frac{(W_h + W_p - W_t)}{W_h + W_p} \cdot 100\,\%.$$

The coefficient of recuperation equals 100% only when W_t equals zero, which corresponds to strictly counterphase change in kinetic and potential energies of the body.

Spectral analysis for determination of forms of static reactions [7] was performed by calculating Fourier coefficients for the first 6 terms in a trigonometric series. Relative amplitudes of each harmonic were calculated using the formula:

$$G_i = \sqrt{A_i^2 + B_i^2} \Big/ \sqrt{A_1^2 + B_1^2},$$

where i is the harmonic number (i = 1, ..., 6), A_i and B_i are Fourier coefficients and G_i is the relative amplitude of the ith harmonic.

Table 1. Changes in weight, circumferences and thickness of skin-fat folds (SFF) in different body segments under the effect of 120-day AOH

Segment	Right after AOH						Recovery period					
	weight, kg		circumference, cm		SFF, mm		weight, kg		circumf., cm		SFF, mm	
	$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}$	σ
Foot	—0,008	0,022	—	—	—	—	+0,032	0,011	—	—	—	—
Lower leg	—0,192*	0,146	—2,28*	1,19	+2,70*	1,643	+0,250	0,161	+2,62	1,559	—0,50	1,00
Thigh	—0,992*	0,523	—2,40*	1,575	+1,00*	2,236	+0,722	0,269	+1,80	0,997	0	2,739
Hand	—0,006	0,056	—	—	—	—	+0,044	0,066	—	—	—	—
Forearm	—0,054	0,167	—	—	—	—	+0,038	0,130	—	—	—	—
Upper arm	+0,140*	0,253	+1,48	2,321	—2,40	5,941	—0,048	0,121	—0,56	1,172	—0,20	2,588
Trunk sections												
upper	+1,150*	0,886	+1,92	2,580	+1,40*	2,945	—0,738	0,702	—0,62	1,958	—0,30	1,255
middle	+1,290*	1,313	+2,72	5,714	+5,00*	5,292	+0,074	0,645	+1,84	2,824	—1,40	2,074
bottom	+0,896*	0,667	+1,00*	1,192	+3,20*	3,114	—0,774	0,601	+0,16	0,921	—1,20	1,304
Head	—0,012	0,141	—	—	—	—	+0,040	0,051	—	—	—	—

Note: A comparison was made of data right after AOH to baseline levels and in the recovery period, to parameters immediately after AOH. Asterisk indicates $P<0.05$. Here and in Table 2, a dash indicates that no data are available.

Results and Discussion

The change in body weight after AOH in different subjects constituted -8.4 to + 8.0 kg; on the average for the group, this parameter decreased by 133 g. The most noticeable changes were in segments with concentration of muscles carrying the main antigravity load (Table 1). Thus, this was manifested in the leg and thigh by a decrease in circumference, increase in skin-fat fold and reduction of weight of these segments in all subjects. The mean changes in these parameters for the group constituted 2.4 cm, +1 cm, -0.922 kg, respectively, for the thigh, 2.28 cm, +2.7 mm and -0.192 kg for the leg. In the trunk, there was increase in thickness of skin-fat folds, while the changes in circumference were in both directions by virtue of individual adaptation of the subjects to experimental conditions. The weight of trunk segments increased on the average: +1.450 kg in the top section, +1.290 in the middle and +0.806 in the bottom one. The fat deposits decreased in the arm, circumference and weight increased (-2.4 mm, +1.5 cm and +1.140 kg, respectively).

The demonstrated changes warrant the belief that reduction of circumferences and concurrent increase in thickness of fat folds are related to reduction of muscle tissue and increase in fat tissue. Where there was excessive replacement of muscle by fat we observed increase in weight of the segment. The decrease in weight of the thigh and leg can be attributed to significant muscular atrophy and insufficient replacement of muscle with fatty tissue, while trunk weight gain can be attributed to the fact that this compensation was excessive.

On the whole, a 2-week recovery period led to reverse processes. The

weight of the thigh and leg reverted to the baseline, there was partial recovery in both the top and bottom sections of the trunk. Table 1 lists the mean changes as compared to posthypokinesia levels. Lesser changes were found in the middle section of the trunk (apparently, it is much harder to reduce fat deposition in the abdominal region). Body weight increased by a mean of 1.325 kg after hypokinesia.

Table 2. Biomechanical characteristics of normal walking and walking after hypokinesia (M±m)

Parameter	Normal walking			Walking 3 days after hypokin.	Walking 2 weeks after AOH		
	slow	average	fast		slow	average	fast
Average speed, m/s	1,06	1,47	1,88	1,011±0,336	1,057±0,061	1,473±0,103	1,877±0,173
Double step length, m	1,20	1,50	1,70	1,468±0,248	1,564±0,256	1,800±0,178	2,002±0,238
Double step time, s	1,20	1,15	0,96	1,711±0,286	1,595±0,100	1,337±0,049	1,208±0,260
Step frequency, cycle/s	0,83	0,87	1,04	0,601±0,111	0,628±0,039	0,746±0,026	0,895±0,060
Work to increase horizontal speed, J/kg-m	0,34	0,42	0,62	0,522±0,144	0,457±0,108	0,587±0,244	0,720±0,300
Work to increase vertical speed, J/kg-m	—	—	—	0,081±0,021	0,089±0,082	0,066±0,047	0,150±0,142
Work to raise GCM, J/kg-m	0,36	0,40	0,48	0,486±0,158	0,541±0,423	0,505±0,248	0,738±0,244
Total work, J/kg-m	0,25	0,30	0,50	0,493±0,171	0,387±0,186	0,357±0,259	0,641±0,029
Recuperation coeff.,%	62	66	64	50,3±16,1	52,3±15,0	59,2±8,1	57,6±7,1
Relative amplitude of harmonics of vertical component of static reaction:							
2	—	0,18	0,24	1,033±0,428	0,919±0,185	1,666±0,338	3,848±1,683
3	—	0,41	0,48	0,399±0,181	0,324±0,110	0,477±0,219	1,010±0,261
4	—	0,05	0,10	0,159±0,081	0,097±0,058	0,165±0,105	0,313±0,135
5 —	—	0,12	0,16	0,068±0,051	0,052±0,027	0,109±0,056	0,261±0,178
6	—	0,02	0,04	0,051±0,033	0,041±0,011	0,099±0,016	0,203±0,104

Note: Data for normal walking were taken from [3, 7-9]. Slow walking is less than 1.167 m/s (4.2 km/h) and fast, over 1.611 m/s (5.8 km/h).

It should be noted that similar results were obtained in a similar study but with 182-day AOH [4].

The biomechanical characteristics of walking after hypokinesia at this stage of the study were compared to analogous parameters of walking in healthy people (normal walking). Table 2 lists the biomechanical characteristics of normal walking and of subjects' walking after AOH. Parameters of walking after hypokinesia differed from normal ones in the following features:

1) greater length (l) and time (t) of double step, lower frequency (f) of steps and number of cycles/s.

2) greater mechanical work performed in walking and lower recuperation of mechanical energy.

3) Order of ranks of amplitudes of harmonics of vertical component of static reaction.

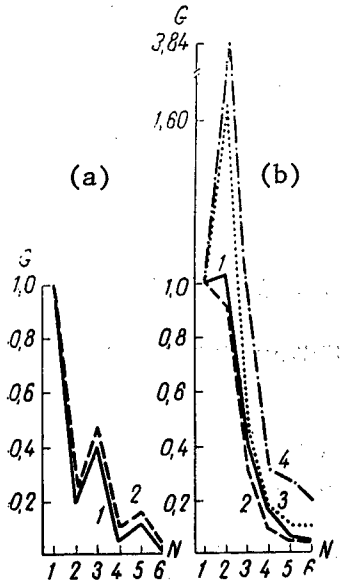
The decrease in frequency of steps as a result of AOH could not be attributed to change in geometry of the subjects' lower extremities (see Table 1). If we consider the lower extremity as a physical pendulum, the period of free oscillations can be defined as:

$$T = 2\pi \sqrt{I/mga},$$

where I is moment of inertia of the leg in relation to the frontal axis of the hip joint, a is distance from center of mass (CM) of the leg to this axis, m is weight of the leg and g is acceleration of free fall. Parameter a showed virtually no change after hypokinesia. There was significant decrease in weight of the leg (by about 10-12%), but this elicited approximately the same decline of inertial moment of the lower limb in relation to the frontal axis. As can be seen from the formula, the period of free oscillations of the lower limb did not change with change in parameters of the subjects' mass geometry. Evidently, the increase in length of steps (and consequently decrease in frequency of steps) immediately after hypokinesia is related to the need to provide better conditions to retain anteroposterior equilibrium (the support area increases in two-support position). After a 2-week recovery period it was apparently easier for the subjects to retain their equilibrium. However, as can be seen in Table 2, the length of the steps did not change (accordingly, the frequency of steps did not increase). This can be attributed to the fact that an increase in frequency of steps (and decrease in length) would lead to increase in external mechanical work (the coefficient of correlation calculated for these parameters in the second test constituted 0.610 with $\alpha = 0.05$).

At all walking speeds after AOH, the different fractions of mechanical work were higher than under normal conditions (see Table 2). On the 3d posthypokinesia day, mechanical energy expenditure during walking were essentially greater than after the 2-week recovery period. The only exception was the parameter of mechanical work in vertical direction. The decrease in work against gravity immediately after hypokinesia is perhaps related to substantial atrophy of leg muscles counteracting gravity. Thus, hypokinesia leads to an increase of mechanical energy expenditure per meter traveled and kilogram of weight when walking, which is indicative of decrease in economy of the subjects' movements.

The coefficient of recuperation characterizes the mechanical energy retained by the body when walking. The more energy is retained, the less work is required of muscles and the more economical is walking. Three days after AOH the recuperation coefficient was significantly below normal (see Table 2). After the 2-week recovery period it increased somewhat. We can conclude from this that the decreased economy of walking after hypokinesia is attributable to both greater values for different fractions of mechanical work performed during locomotion and decrease in recuperation of energy.



Relative amplitude of harmonics (G) of vertical component of static reaction vector

a) normal walking [2, 3, 6]:
   1) average rate
   2) above average
b) walking after hypokinesia:
   1) immediately after AOH (slow)

2, 3, 4) 2 weeks after hypokinesia, slow, average and fast walking

The relative amplitudes of harmonics of the vertical component of the vector of static reaction in walking after AOH differ appreciably from normal (see Figure and Table 2). Thus, for normal walking the ranking of amplitudes of the first 6 harmonics is distributed as follows: 1, 3, 2, 5, 4, 6. For walking after hypokinesia it is different: 2, 1, 3, 4, 5, 6 immediately after hypokinesia (slow), 1, 2, 3, 4, 5, 6 after a 2-week recovery period for slow walking, 2, 1, 3, 4, 5, 6 for average walking and 3, 1, 2, 4, 5, 6 for fast walking. One observes an increase in amplitude of the second harmonic when walking after hypokinesia (the corresponding frequency when walking at different speeds is 2.0-3.5 Hz). There is also significant increase in amplitude of the third harmonic (4.5-5.5 Hz) when walking fast.

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FUNCTIONAL ACTIVITY OF HUMAN SEROTONINERGIC AND HISTAMINERGIC SYSTEMS DURING LONG-TERM ANTIORTHOSTATIC HYPOKINESIA

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 19, No 5, Sep-Oct 85 (manuscript received 3 Feb 84) pp 27-30

[Article by N. A. Davydova, Ye. Yu. Galkina and A. S. Ushakov]

[English abstract from source] The functional activity of serotonin- and histaminergic systems was investigated during 120-day head-down tilt. Serotonin excretion was increased until test day 70 and histamine excretion throughout the entire study. At the final stage of exposure (test days 100-120) the serotonin content decreased. Return to the normal motor activity stimulated the function of serotonin- and histaminergic systems.

[Text] Weightlessness is the specific factor of spaceflights. Its effects are studied on the ground in model experiments, in particular, with use of hypokinesia. Serotoninergic and histaminergic systems (SES and HES) play an important part in neurohumoral regulation of changes that occur during prolonged restriction of movement [4, 7]. Investigation of the activity of these systems using modern methods and criteria for assessing their activity permits finding approaches to the solution of some problems of prevention and correction of metabolic changes.

Our objective here was to test human SES and HES activity during long-term antiorthostatic [head-down tilt] hypokinesia.

Methods

These studies were conducted on 6 healthy male subjects 25 to 40 years of age who were submitted to AOH (-4.5°) for 120 days. Venous blood and 24-h urine served as material for the study. Venous blood was drawn once in the baseline period (active motor exercise under hospital conditions), on the 25th, 56th, 70th, 95th, 112th days of AOH and on the 1st, 7th, 14th and 25th days of the recovery period. We collected 24-h urine in the baseline period at the same time as drawing blood, on the 4th, 10th, 25th, 32d, 52d, 75th, 100th, 112th, 120th days of AOH and on the 4th and 8th days of the recovery period. The subjects were kept on a controlled diet. No additional functional tests or loads were used during the period of collecting biological specimens. SES and HES activity was studied by determining concentrations of tryptophan (T),

5-hydroxytryptophan (5-HOT), serotonin (S), histamine (H), histidine (HD) in venous blood and 24-h urine, as well as 5-hydroxyindoleacetic acid (5-HOIA) in 24-h urine [1]. For qualitative evaluation of functional activity of the systems in question, we calculated coefficients characterizing relative activity of processes of synthesis and metabolism of S and H [8], as well as the S/H ratio [8]. The obtained results were submitted to processing by the method of variational statistics using Student's criterion for dynamic observations.

Results and Discussion

In the background period, levels of S, H and their precursors, concentration of metabolites in blood and their excretion in urine (Tables 1 and 2), as well as parameters of relative activity of S and H metabolism (according to results of urinalysis; see Figure) were in the range of the physiological norm.

The initial stage of hypokinesia (4th-10th days) was associated with intensification of excretion of T, 5-HOT and SNH [obvious typo] in urine, as compared to the baseline. Parameters of relative activity of S and S/H ratio were at the base level, which is indicative of increased discharge from the pool of S and its precursors without change in intensity of synthesis. The high level of S is probably due to hemodynamic changes that develop in antiorthostatic position, as well as the emotional reaction to AOH conditions [3, 7], as indicated also by activation of the sympathoadrenal system [3]. Thereafter T level in blood and its excretion in urine gradually diminished, whereas S, 5-HOT, 5-HOIA levels in blood and excretion in urine on the 32d, 52d and 56th days of AOH were significantly above baseline values. There was dramatic rise of 5-HOT/T ratio (see Figure), which could be indicative of relative activation of 5-HOT synthesis at these times. The S/5-HOT ratio exceeded baseline values from the 52d to 70th days of AOH, which is apparently related to relative activation of S synthesis. Up to the 70th day of AOH, relative activity of S inactivation processes was diminished (5-HOIA/S) in the presence of high 5-HOIA level in urine, probably due to drastically increased secretion of S, which was maintained by decline of its inactivation. The obtained data are indicative of marked activation of the SES, which is correlated with development of the asthenoneurotic syndrome, signs of vegetovascular dysfunction and other disturbances [3, 5, 6] in the subjects, combined with activation of the hormonal element of the sympathoadrenal system.

At the final stage of AOH (100th-120th days) there was decline of blood and urine S and increase in relative activity of processes of transmitter (5-HOIA) inactivation processes, whereas relative synthetic activity (S/5-HOT) was below the baseline at these times (see Figure).

Thus, after 70 days of AOH, activation of SES was followed by decline of activity probably due to development of mechanisms of adaptation to AOH, on the one hand, and development of a reaction to diminished afferent impulsation, on the other [9, 10].

Blood and urine H concentration exceeded baseline values throughout the AOH period, HD level dropped gradually, while H/HD ratio exceeded the baseline significantly (see Figure), which is indicative of intensification of relative activity of H synthesis. The high level of H in the body should be interpreted

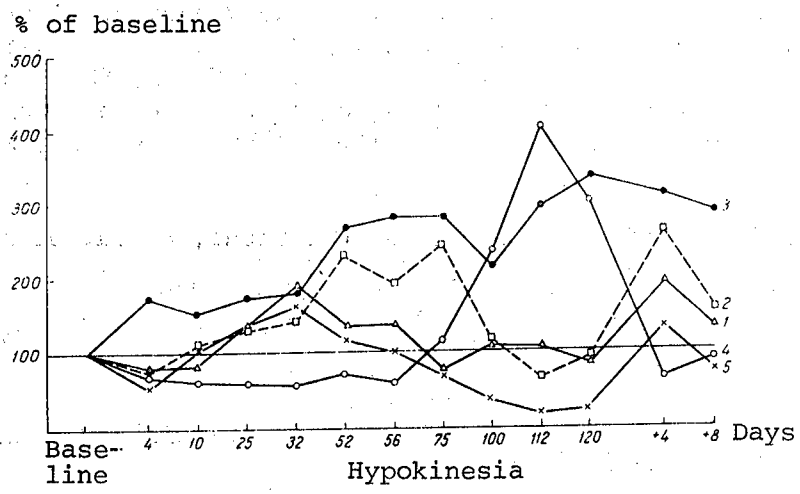
Table 1. Levels of S, H and their precursors in subjects' blood (M±m)

Parameter	Baseline	Days of hypokinesia					Recovery day			
		25	56	70	95	112	1	7	14	25
T, μmol/ℓ	33,3±2.46	20.6±4.79	23,2±6.74	19,2±7,95	21,4±13.1	26.4±12.0	15.6±3.38	34.8±15.6	40,3±8.42	36.5±4,76
P		<0.001	<0,05	<0,05						
5-HOT, μmol/mℓ	8,22±1,82	6,18±1,52	9,06±2,58	22,2±2,39	23,6±1.60	16.6±1,97	30.9±3.49	25.9±2.72	14.4±1.79	10.4±1.48
P				<0,02	<0,02	<0,05	<0.01	<0.02		<0.05
S, μmol/ℓ	0,31±0,03	0,93±0,24	1,19±0,07	1,56±0,10	1,10±0.09	1.37±0,25	2,10±0.35	0.72±0.15	0,47±0.03	0,38±0,02
P		<0,001	<0,02		<0,001	<0,02	<0.05	<0.01	<0,02	
H, μmol/ℓ	0,44±0,25	0,40±0,04	0,89±0,04	1,10±0,13	1,03±0.07	1.07±0.06	1.03±0.28	1.19±0.09	0.53±0.04	0.32±0,06
P			<0,05	<0,05						
HD, μmol/ℓ	36.5±9,22	40,9±17,6	26,3±17,1	25,5±13,0	28,0±10,9	37,9±19,9	28.9±9.72	33.6±24.8	35,8±5.98	35.4±9,61
P				<0,05						

Table 2. Excretion of S, H, their precursors (in μmol/day) and metabolites (M±m)

Para-meter	Base-line	Day of hypokinesia										Recovery day	
		4	10	25	32	52	56	75	100	112	110	4	8
T	52.2±0.0	72,0±0,0	65,5±10,4	55,5±15,5	48,4±9,12	43,7±15,8	43,08±16,4	33.3±16.5	30,5±19.2	27,3±16.5	27.8±18.5	43,1±28,8	58.0±25.1
P					<0,05	<0,001	<0.001	<0.001	<0,001	<0,01	<0,01	<0,01	
5-HOT	0.89±0.26	1,13±0,11	1,25±0,29	1,62±0.51	1,74±0,79	1,16±0,45	1,15±0,37	0,51±0,46	0,64±0.31	0.56±0.32	0.48±0.28	1,64±0,80	1,49±0,34
P				<0,05	<0,01							<0.05	
S	0.70±0.11	0,63±0,19	1,06±0,18	1,75±0,65	1,98±0.68	2,00±0,92	1,69±0,27	0,99±0,30	0.54±0.19	0,26±0,12	0.34±0,05	3,42±0,25	1,85±0,25
P				<0,02	<0,02	<0,001	<0,001			<0,02	<0.01	<0.001	<0,02
5-HOIA	16.3±4,64	11,0±5,23	15,5±7,95	23.1±7,95	26,7±4,58	29,2±7,93	21,5±10,9	26,4±19,8	28.9±13.3	24.6±19.2	24.0±17,4	54.0±35,4	41,4±9,8
P					<0,01	<0,01			<0,01			<0,001	<0,001
H	0.57±0,10	0,93±0,28	0,84±0,40	1,01±0.24	1,01±0,30	1,29±0,29	1,35±0.47	1,28±0.62	1,04±0.47	1,40±0,49	1.32±0,65	2,02±0,63	1,75±0,24
P				<0,01	<0,01	<0,02	<0.02	<0,02		<0,001	<0.01	<0,001	<0,001
HD	688,3±90,3	662,0±73.5	668,0±123,3	733,9±30,2	695,6±75,0	619,4±38,2	614,0±56,1	582,5±40,0	606,0±59.6	600,8±76,0	485,5±115,0	784,3±70,8	778,0±45,4
P				<0,05				<0,05			<0,05	<0,01	<0,02

as an adverse factor causing allergization, which must be taken into consideration when elaborating preventive measures for such conditions.



Parameters of relative activity of S and H metabolism under AOH conditions (according to results of urinalyses). Estimates were made on the basis of mean data

1) 5-HOT/T 2) S/5-HOT 3) H/HD 4) 5-HOIA/S 5) S/H

Return to normal motor activity elicited significant elevation of T, 5-HOT, S, H, HD in blood and urine (see Tables 1 and 2) and increase in relative activity of metabolic processes (see Figure). This is indicative of considerable strain of functional activity of SES and HES, which is related to the body's increased need to intensify the tonus of the vasomotor center, skeletomuscular system and metabolic processes [3].

By the end of the recovery period (25th day), activity of the tested systems reverted to the base level, which was indicative of the functional nature of demonstrated changes.

Thus, long-term AOH elicits changes in functional activity of SES and HES; it is associated with impairment of S and H metabolism, which could serve as the cause of adverse changes in the nervous, cardiovascular and other systems of the body [2].

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BODY POSITION DURING HYPOKINESIA, AND FLUID-ELECTROLYTE METABOLISM

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 19, No 5, Sep-Oct 85 (manuscript received 7 May 84) pp 31-34

[Article by V. B. Noskov, G. I. Kozyrevskaya, B. V. Morukov, Ye. M. Artamasova and L. A. Rustam'yan]

[English abstract from source] Two groups of 5 healthy volunteers each were exposed for 7 days to: 1) group 1 to horizontal bed rest and 2) group 2 to head-down tilt at -6°. The purpose of the study was to determine the effect of body position on fluid-electrolyte metabolism and renal function. During the control period (14 days days), bed rest and the recovery period the consumption of fluids and mineral substances and their renal excretion were measured. The typical changes in fluid-electrolyte metabolism during head-down tilt developed faster than during horizontal bed rest. The fluid-electrolyte balance became negative in the course of the exposure and returned to normal during the recovery period. The group 2 subjects showed greater body weight losses due to both fluid and muscle mass losses.

[Text] Several studies have been conducted in recent years that were aimed at developing an adequate model to reproduce the basic phenomenology of functional changes in human organs and systems in weightlessness [1, 5, 10]. Bedrest with the body in different positions in relation to the vector of gravity is the most popular model [2, 4, 11].

Our objective here was to assess fluid-electrolyte metabolism and electrolyte excreting renal function in the course of submitting healthy subjects to bedrest in horizontal or head-down tilted position in order to validate a more adequate model of the effect of weightlessness on fluid-electrolyte homeostasis.

Methods

Two groups of healthy men (5 in each group) were kept on strict bedrest for 7 days. The 1st group of subjects remained in horizontal position and the 2d, in antiorthostatic position (AOP) with the head end of the bed tilted down at an angle of 6°. The two groups of subjects differed in anthropometric parameters (weight, height, body surface). All of them were on a standard diet with controlled water intake both in the baseline period (BP) lasting

14 days and during bedrest (BR) and the recovery period (RP). For the first 7 days of the BP, the subjects adapted to their diet and for the next 7 days we gathered baseline, control values for the tested parameters. Water intake was not limited, but a strict record was kept of total fluid input, which was the sum of beverages included in the diet, water content of foods and additional water consumed by the subjects. Their diet consisted of canned goods in three assortments, which were similar in mineral content but offered some variety to the daily menus. Caloric value of the diet was 2500-2800 kcal/day. To determine moisture content of the diet and its mineral composition, a control assortment of foods was homogenized, dried to a constant weight, then ashed and mineralized.

Microclimate parameters were stabilized at an ambient temperature of 22-24°C. Urine was collected daily and each individual batch was decanted into a separate bottle and stored under refrigeration (4°C). Upon completion of collection of 24-h specimens, we measured volume of urine, and the part to be used for assaying electrolytes was acidulated with nitric acid. Both diet mineralizates and 24-h urine were tested for sodium and potassium levels by flame photometry, chlorides were assayed by titrometer; calcium and magnesium by the method of atomic absorptiometry and creatinine by the Jaffe reaction.

Considering that the diet consisted of three assortments of foods differing, though insignificantly, in mineral composition, to assure accuracy of the tests, we calculated daily the percentage of renal excretion, which is the ratio of excreted tested substances to their uptake expressed as percentage. Since the subjects varied significantly in body weight (65 to 85 kg), several parameters were scaled to 1 kg weight to obtain more comparable data.

Mathematical analysis of the dynamics of the parameters under study during hypokinesia was performed with consideration of the individual values for each subject in the background period.

Results and Discussion

Examination of mineral composition of the food allowances revealed that the subjects received in their food an average of 174±25 meq sodium, 63±2 meq potassium, 42±7 meq calcium and 27.0±0.6 meq magnesium daily in all periods. Total fluid intake in the last 7 days of BP constituted 33.9±1.0 and 31.3±1.0 mℓ/kg in the 1st and 2d groups, respectively, the figures being 22.6±1.9 and 26.6±1.0 mℓ/kg as the average for the BR period, i.e., fluid intake dropped appreciably in both groups after starting BR. After the subjects returned to their usual lifestyle, fluid intake remained on the level inherent in the BR period (Figure 1c).

The results of a previous study [3, 6, 8] revealed that when man changes to BR and there is redistribution of body fluids in a cranial direction as a result of triggering cardiorenal reflexes, a hormonal change occurs that leads to decline in reabsorption of fluid and electrolytes in the renal tubules and their increased excretion in urine. However, no marked changes in diuresis were demonstrable during BR, but after changing to BR both groups of subjects showed an increase in relative fluid loss, since fluid intake diminished (see Figure 1c). Calculation of percentile renal excretion

of fluid is the most objective parameter of changes in hydration of the body, since it considers the changing level of fluid intake (Figure 1b). As can be seen in this figure, excretion of fluid on the 1st day of hypokinesia increased 1.2 times more in the 2d group than the 1st, but on the whole, renal excretion of fluid during BR was reliably higher than the baseline level in the 1st group of subjects. However, it should be borne in mind that the baseline value of this parameter was substantially lower for the subjects in the 1st group than in the 2d.

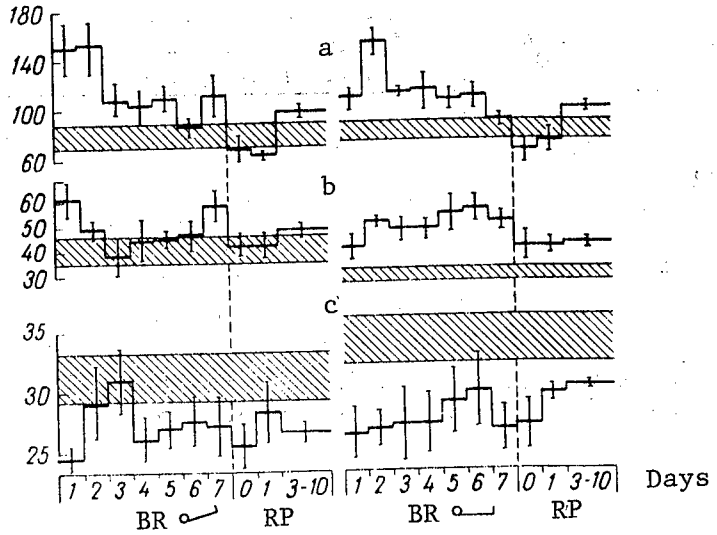

Figure 1. Daily sodium (a) and fluid (b) excretion in urine as compared to intake (%, M±m), and fluid intake (c, mℓ/kg, M±m) during BR and in RP. Here and in Figure 2 baseline is crosshatched (7-day mean, M±2m)

A comparison of data on fluid intake and diuresis in the background period and during hypokinesia revealed in some subjects a significant decline of fluid intake with virtually unchanged diuresis after changing to BR, whereas in others fluid intake diminished less, but diuresis increased, by almost 10 times in some cases. Thus, individual adaptive alteration of fluid-electrolyte equilibrium during hypokinesia, which is aimed at lowering fluid content of the human body, occurs via different pathways but leads to the same end result.

From the first day of BR, all subjects also presented an increase in natriuresis and rate of glomerular filtration, as assessed by creatinine excretion. The dynamics of development of these changes were attributable to the position of the subjects' body. Thus, in the 2d group, development of profuse diuresis and intensification of sodium excretion in urine were observed virtually immediately after changing to BR, but in the 1st group only after the 2d-3d day of hypokinesia. During BR, the 1st group of subjects presented reliably increased natriuresis from the 2d to 5th days, but on the last 2 days its level did not exceed the baseline. Reliable increase in natriuresis was observed in the 2d group of subjects throughout the hypokinetic period. However, a statistically significant differences between parameters of the two groups was demonstrable only on the 1st day of BR, when natriuresis was almost 1.5 times more marked in the 2d group than in the 1st (see Table). The dynamics of

chloride excretion corresponded to sodium excretion in urine at all stages of the study. Analysis of sodium excretion as related to its intake with food (Figure 1a) revealed that, during BR, the percentile excretion of sodium in urine increased in both groups of subjects, but the dynamics of changes depended on the subjects' position.

Daily excretion of tested substances at different stages of study in 1st and 2d group of subjects (M±m)

Parameter	BP mean (n=10)	1st day of BR		1st day of RP	
		1st group	2d group	1st group	2d group
Diuresis, mℓ/kg	11,3±0,5	10,3±0,5	15,3±2,7*	10,6±0,8	10,8±1,3**
Sodium, meq	137±3	175±14*	239±20*	105±8**	108±15**
Potassium, meq	49±1	41±5	49±5	63±6	53±5
Calcium, meq	9,2±0,4	8,3±1,0	10,9±2,0*	8,9±0,3	11,2±0,7
Magnesium, meq	8,5±0,2	8,1±0,3	9,2±0,4	9,3±1,0	11,9±1,6
Chloride, meq	138±4	153±10	200±24*	142±12	147±9**
Sodium/potassium	1,05±0,04	1,8±0,3*	2,0±0,2*	0,64±0,02**	0,83±0,08**
Creatinine, mmole	19,4±0,3	17,7±1,8	22,1±3,5*	18,6±1,8	22,1±2,7

*Statistically reliable difference in comparison to BP (P<0.05).
**Statistically reliable difference in comparison to BR (P<0.05).

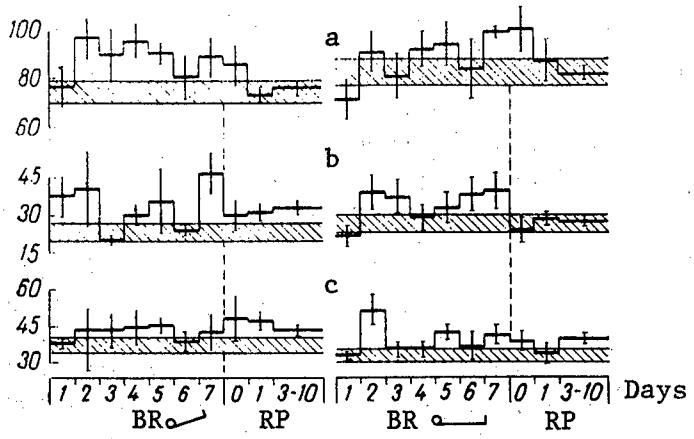

Figure 2. Daily excretion in urine of potassium (a), calcium (b) and magnesium (c) as related to intake (%, M±m) during BR and RP

Potassium and calcium excretion was more marked in the 2d group of subjects (Figure 2a and b). As can be seen in this figure, calcium excretion in urine (like that of sodium) increased from the first days of BR in AOP. Such rapid and, furthermore, position-related increase in renal excretion of electrolytes indicates that hemodynamic changes and concomitant alteration of hormonal regulation of fluid-electrolyte metabolism and renal function are the etiological and, perhaps, triggering factor of these changes. We failed to detect any pattern of change in magnesium excretion in urine, and individual reactions were more relevant than the effect of hypokinesia (Figure 2c).

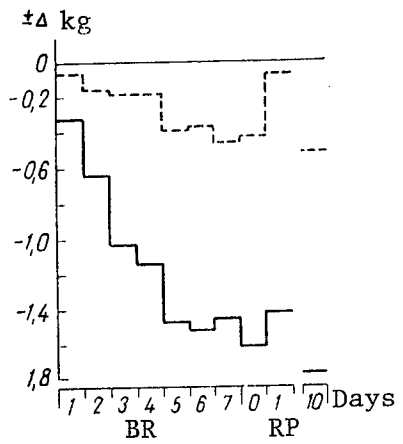

Figure 3.
Dynamics of mean-group values for change in body weight as compared to individual base values (zero level); dotted and solid lines--1st and 2d groups, respectively

Thus, there is increased renal excretion of fluid and electrolytes during BR, and this develops faster and more intensively in AOP. Consideration of minerals in the diet and urine enabled us to assess quantitatively the balance of different elements. The negative sodium balance constituted 280±48 meq at the end of BR in the 1st group of subjects and 387±78 meq in the 2d (the difference was statistically unreliable). These changes in fluid-electrolyte metabolism and excretory function of the kidneys at different stages of our study were associated with typical hormonal change: the sodium-potassium ratio was indicative of depression of mineralocorticoid activity of the adrenals during hypokinesia and its significant activation after changing to a usual mode of life (see Table).

Upon termination of the BR period, both groups of subjects presented statistically significant fluid and sodium retention, as compared to the hypokinetic period (see Figure 1 and Table). This reaction should be assessed as adequate and necessary to make up the shortage of these extremely important components of the body that developed during hypokinesia. It develops due to increased tonus of antidiuretic and antinatriuretic systems in response to the diminished flow of blood to the upper part of the body, and it is aimed at restoring optimum proportion between circulating blood volume and capacity of the vascular system [7, 9]. During and after BR there were no appreciable changes in ion composition of blood serum and its osmolarity. Analysis of the obtained data indicates that individual reactions make a considerable contribution to formation of the mean-group distinctions that often obscure the effect of the basic exposure factor.

Hypokinesia was associated with weight loss, and its extent was related to the position of the body (Figure 3). Weight loss by the end of the 7th day of BR constituted 1.6±0.2 kg in the 2d group and only 0.4 kg in the 1st group, and 2 men in this group gained 0.2 kg. On the first days of the RP, both groups of subjects showed no increase in fluid intake, but about the same fluid retention, which was reflected by an increase in body weight by a mean of 0.4±0.2 and 0.2±0.1 kg for the 1st and 2d groups of subjects, respectively. None of the subjects complained of insufficient food, but considering that the mean group weight in the 2d group was initially 8 kg higher than for the 1st group, it can be assumed that the caloric value of the food allowance did not conform entirely to the energy expenditures of the 2d group of subjects and they lost more solid tissue. The dynamics of excretion of potassium and calcium, which are the principal mineral components of tissues of the skeletomuscular system (see Figure 2a and b) are also indicative of development of atrophic processes. This assumption is also confirmed by the fact that, even on the 10th day of the RP, body weight was not restored to the base level in either the 1st or 2d groups, and it was 0.5±0.3 and 1.8±0.3 kg lower,

respectively, in spite of the retention of fluid and sodium from the first day of the recovery period.

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MICROCIRCULATION AND CELLULAR HEMOSTASIS IN MEN WITH BORDERLINE ARTERIAL HYPERTENSION SUBMITTED TO NEUTRAL-TEMPERATURE 'DRY' IMMERSION IN WATER

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 19, No 5, Sep-Oct 85 (manuscript received 6 Sep 83) pp 35-38

[Article by L. L. Kirichenko, V. V. Smirnov and A. G. Yevdokimova]

[English abstract from source] Platelet hemostasis, microcirculation, blood viscosity and lipid metabolism were examined in 18 men with borderline hypertension and 8 healthy men before, during and after 7-day immersion. The exposure to thermoneutral dry water immersion produced hypercoagulopathic changes of platelet hemostasis in the healthy and hypertensive subjects. Platelet hemostasis returned to the pretest level in the health subjects 2 days and in the hypertensive subjects only 5 days after exposure. Prior to immersion the hypertensive subjects showed signs of capillarotrophic insufficiency which increased after exposure. On immersion day 3 the hypertensive subjects exhibited a higher blood viscosity and a larger content of total lipids and free fatty acids. All the parameters returned to normal 2 days after immersion.

[Text] The importance of the thrombocyte element of hemostasis is well-known at the present time. It was established that thrombocyte aggregation can be induced by molecules of adenosine diphosphate (ADP) released from surrounding tissues and erythrocytes [9] or from an atheromatous plaque [3, 4]. ADP is the best studied aggregating agent. Aggregation induced by ADP depends on pH, temperature and concentration of ADP. Aggregation occurs faster and is irreversible with increase in ADP concentration [8].

There are extremely few works dealing with cellular hemostasis under hypodynamic and hypokinetic conditions [6]. Investigation of the state of microcirculation is an extremely important task for modern clinical and experimental medicine. The effect of long-term hypokinesia on the human microcirculatory system is of definite theoretical and clinical interest [1]. At the same time, there have been no studies to date of microcirculation in the case of neutral-temperature "dry" immersion in water. The state of lipid metabolism and viscosity of blood have a substantial effect on microcirculation and thrombocyte hemostasis.

Our objective here was to study thrombocyte aggregation induced by ADP and epinephrine, changes in thrombocyte count, microcirculation, lipid metabolism and blood viscosity in individuals with borderline hypertension during 7-day "dry" immersion in water at neutral temperature.

Methods

The model of "dry" immersion [7] was used in this study with simulation of weightlessness. A total of 18 male subjects 45-55 years of age with borderline hypertension (BH; in the WHO classification) participated in the tests. The control group consisted of 8 healthy subjects.

Parameters of cellular hemostasis were analyzed before immersion, on the 3d and 7th days of immersion, as well as 48 h after immersion. Thrombocyte hemostasis parameters were determined in 8 men with BH 5 days after immersion.

Fasting blood was drawn in the morning with the subjects in supine position. Blood was tested within the first 2 h after collection from the ulnar vein. Induced aggregation was determined by the method of Born as modified by O'Brien on a Sienco (United States) Aggregometer. Freshly prepared solutions of ADP and epinephrine from the Serva firm (United States) were used as inducers in end concentrations of $4.48 \cdot 10^{-5}$ and $1.82 \cdot 10^{-5}$ M, respectively; thrombocytes were counted by the method of T. F. Berentsova and M. T. Shubich.

Microcirculation was examined by the method of biomicroscopy of bulbar conjunctiva under a ShchL-56 slit lamp with qualitative evaluation of microcirculatory changes. Microvascular blood flow was examined in 17 subjects with BH before immersion and within the first 2-3 h after immersion.

Biomicroscopy using the ShchL-56 slit lamp with a photorecording device permits examination of terminal blood flow in the conjunctiva in three directions: perivascular, vascular and intravascular changes. The four grades of Knizelli's phenomena were assessed by the classification of Ditzel.

Blood viscosity was determined in six subjects with BH. To measure this parameter we used a rotating viscosimeter with free-floating cylinder using the method of V. N. Zakharova et al. This method permits testing viscosity of blood over a wide range of shear stresses. We examined viscosity at shear stress levels of 0.7-5.0 dyne/cm^2. Blood was drawn from the ulnar vein, mixed with 3.8% sodium citrate solution in a ratio of 1:9. In the same six subjects we examined lipid metabolism using thin-layer chromatography with densitometry of platelets. Blood was decanted into test tubes with ground-glass stoppers in amounts of 10 mℓ. We assayed total lipids and nonesterified fatty acids (NEFA) in blood serum. The studies of blood viscosity and lipid metabolism were performed before immersion, on the 3d and 7th days of immersion and 48 h after immersion.

Results and Discussion

Thrombocyte count and parameters of aggregatograms (AG) induced by ADP and epinephrine before immersion did not differ appreciably in subjects with BH from the same parameters of the control group (Tables 1 and 2).

Table 1. Changes in thrombocyte count, ADP- and epinephrine-induced thrombocyte aggregation, total lipids, NEFA and blood viscosity in subjects with borderline hypertension during immersion

Parameter	Baseline	Immersion, day		Recovery period	
		3	7	48 h	5 days
Thrombocytes/mm^3	315,440±12,320	330,000±12,450 $P>0,05$	370,000±12,450 $P<0,05$	360,000±12,620 $P<0,05$	310,000±12,300 $P>0,05$
ADP-induced aggregation:					
i_a (rel.%)	40,62±2,89	59,05±4,5 $P<0,05$	60,9±5,75 $P<0,05$	53,21±4,21 $P>0,05$	42,84±6,01 $P>0,05$
t_a, min	3,98±0,97	6,79±1,27 $P<0,05$	7,13±1,67 $P<0,05$	5,34±1,04 $P<0,05$	3,0±0,28 $P>0,05$
i_d, rel.%	35,33±1,28	irreversible	irrevers.	irrevers.	31,24±2,08 $P>0,05$
t_d, min	14,50±1,77	irrevers.	irrevers.	irrevers.	16,41±2,22 $P>0,05$
Epinephrine-induced aggregation:					
i_a (rel.%)	48,2±5,7	51,4±3,0 $P>0,05$	58,8±3,2 $P<0,05$	64,6±4,29 $P<0,05$	49,81±3,14 $P>0,05$
t_a, min	5,91±0,96	6,32±0,85 $P<0,05$	6,88±0,64 $P<0,05$	6,94±1,28 $P>0,05$	5,0±0,86 $P>0,05$
i_d, rel.%	30,05±4,3	irrevers.	irrevers.	irrevers.	29,1±5,2 $P>0,05$
t_d, min	16,8±2,03	irrevers.	irrevers.	irrevers.	17,92±4,03 $P>0,05$
Total lipids, mg%	526,0±44,5	724,3±87,0 $P<0,01$	699,3±41,2 $P<0,01$	533,2±54,0 $P>0,05$	—
NEFA, mg%	21,08±2,83	30,08±3,0 $P<0,02$	31,08±3,5 $P<0,02$	18,78±2,7 $P>0,05$	—
Blood viscosity, cpoise:					
at 5.0 dyne/cm^2	4,46±0,33	5,20±2,20 $P>0,05$	4,55±0,54 $P>0,05$	4,48±0,40 $P>0,05$	—
at 0.7 dyne/cm^2	6,63±0,32	8,46±3,46 $P>0,05$	6,81±1,10 $P>0,05$	6,76±0,51 $P>0,05$	

On the 3d day of immersion there was a tendency toward increase in thrombocyte count, intensity of aggregation (i_a) and time of aggregation (t_a) on ADP and epinephrine. The AG changes were irreversible. The dynamics of thrombocyte hemostasis became even more demonstrative on the 7th day of immersion: reliable increase in number of thrombocytes, i_a and t_a. The AG changes remained irreversible (see Tables 1 and 2).

All this indicates that activity of thrombocytes and their aggregation ability increased with increase in immersion time.

Table 2. Changes in thrombocytes, ADP- and epinephrine-induced aggregation of thrombocytes in healthy subjects during immersion

Parameter	Baseline	Immersion, day		Recovery period (48 h)
		3	7	
Thrombocytes/mm^3	312 000 ±9600	320 000±10 500 $P<0,05$	350 000±11 350 $P<0,05$	310 000±10 280 $P>0,05$
ADP-induced aggregation, i_a, rel.%	42,88±3,07	57,7±5,1 $P>0,05$	59,08±4,35 $P>0,05$	43,50±4,25 $P>0,05$
t_a, min	2,84±0,78	5,03±0,25 $P<0,02$	6,14±0,77 $P<0,02$	3,12±0,28 $P>0,05$
i_d, rel.%	32,4±2,02	irreversib.	irrevers.	27,4±1,83 $P>0,05$
t_d, min	15,0±1,5	irrevers.	irrevers.	14,8±1,12 $P>0,05$
Epinephrine-induced aggregation, i_a, rel.%	47,9±4,33	52,3±3,5 $P>0,05$	60,23±3,30 $P>0,05$	49,36±3,92 $P>0,05$
t_a, min	4,90±0,99	5,8±0,73 $P>0,05$	5,90±1,1 $P>0,05$	4,92±0,92 $P>0,05$
i_d, rel.%	27,03±2,1	irrevers.	irrevers.	24,8±1,03 $P>0,05$
t_d, min	16,3±2,2	irrevers.	irrevers.	17,30±2,88 $P>0,05$

Changes in the same direction occurred in parameters of thrombocyte hemostasis in both healthy subjects and those with BH, which should apparently be attributed to adaptive changes in response to dry immersion.

In the recovery period (2d day), healthy subjects showed return to baseline values of all parameters of cellular hemostasis, unlike those with BH, in whom ADP-induced thrombocyte aggregation remained high 48 h after immersion and epinephrine-induced aggregation became even higher (see Table 1). The AG changes remained irreversible. Thrombocyte count also remained high. Normalization of thrombocyte hemostasis parameters occurred in subjects with BH only on the 5th day after immersion: thrombocyte count dropped to the base level, AG changes became irreversible, ADP- and epinephrine-induced aggregation capacity came close to baseline values (see Table 1).

Thus, the obtained data indicate that 7-day dry immersion in water at neutral temperature leads to substantial changes in cellular hemostasis in both health subjects and those with BH.

Examination of microcirculation in 17 subjects with BH before immersion revealed marked perivascular lipoidosis and perivascular hemorrhages. The vessels were altered: there was tortuosity of both venules (with enlargement of their caliber) and arterioles; vascular caliber was uneven; we encountered isolated venular microaneurysms; capillaries of the limbus were dilated. Intravascular blood flow was slow, erythrocyte aggregates were encountered in venules of small caliber and capillaries (grade I-II Knizelli phenomenon).

After immersion, virtually all subjects presented worsening of microcirculatory parameters. There were significant changes in the intravascular bed. Slower blood flow was noted in many limbic capillaries and some arterioles, with

appearance of erythrocyte aggregates. Slowing of capillary blood flow was associated with stasis, grade II-III Knizelli phenomenon. Erythrocyte aggregation extended to large-caliber venules. Perivascular hemorrhages appeared. There were virtually no changes in vascular parameters.

Thus, on the basis of these studies it can be concluded that immersion caused worsening of microcirculation in the subjects, mainly due to increased intravascular aggregation of erythrocytes with slowing of vascular blood flow. The changes in the microvascular system of bulbar conjunctiva enable us to conclude that processes of tissular blood flow are impaired during immersion, with worsening of homeostasis and development of signs of cappilarotrophic insufficiency.

Examination of blood viscosity in six subjects with BH revealed a tendency toward increase on the 3d day of immersion, and it gradually decreased to normal values by the end of the immersion period (see Table 1). Examination of lipid metabolism revealed reliable increase in total lipid content by the 3d day of immersion ($P<0.01$), followed by decrease to the base level after 48-h recovery (see Table 1). There were analogous changes in NEFA content (see Table 1).

No doubt, the changes in blood viscosity and lipid metabolism in subjects with BH had an adverse effect on thrombocyte and erythrocyte hemostasis, as well as microcirculation as a whole.

Stress, elevated levels of free fatty acids and changes in blood viscosity intensified thrombocyte aggregation. Vascular lipoidosis and perivascular hemorrhages activated the blood-clotting process. Appearance of collagen strands led to activation of factor XII and, consequently, to activation of entire plasma hemostasis, on the one hand, and it was instrumental in thrombocyte adhesion at the site of injury with subsequent release of thrombocytes, on the other hand. The biologically active agents (epinephrine, histamine, ADP) present in thrombocyte granules, after being released, changed the aggregation process into a self-sustained one.

These findings may be indicative of hypercoagulopathic tendencies in the blood-clotting system, as well as inertia of adaptive mechanisms in the system of both plasma and cellular hemostasis in individuals with BH. In the opinion of several authors [2, 6, 10], the increase in coagulation potential of blood and particularly its thrombocyte element under conditions simulating weightlessness is attributed to slowing of blood flow, impairment of vascular permeability, discharge of coagulants and biologically active compounds from formed elements, increased acidosis and, according to our data, also to decrease in fibrinolytic activity of blood and decline of α_1-antitrypsin [5], development of capillarotrophic insufficiency in the microvascular bed, increase in free fatty acid content and viscosity of blood.

Considering all these circumstances, one should prescribe for individuals with borderline hypertension compounds that increase FAK [fibrinolytic activity of blood?], reduce thrombocyte aggregation and lower free fatty acid levels.

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EFFECT OF POSITIVE PRESSURE BREATHING ON HEMODYNAMICS IN PATIENTS WITH BORDERLINE HYPERTENSION SUBMITTED TO WATER IMMERSION

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 19, No 5, Sep-Oct 85 (manuscript received 10 May 84) pp 39-41

[Article by V. N. Orlov, I. O. Fomin, A. E. Radzevich and G. S. Leskin]

[English abstract from source] Patients with borderline hypertension were exposed, while being immersed, to positive pressure breathing. During exposure cardiac output (CO), heart rate (HR), mean arterial pressure (MAP), total peripheral resistance (TPR), left ventricle work (W), blood content of head vessels (Q_h), upper and lower lung lobes (Q_{ul} and Q_{ll}), liver (Q_l) were measured. During immersion, CO and MAP decreased, HR and TPR increased slightly, and W diminished. Simultaneously, Q_h, Q_{ul} and Q_{ll} increased significantly while Q_l decreased considerably, indicating blood "centralization" during simulated microgravity. Courses of positive pressure breathing led to decreases in Q_h, Q_{ul}, Q_{ll} and increase in Q_l, i.e., they caused blood to be displaced from the head and lungs to the liver. Thus, the liver plays the role of a physiological pool which accumulates blood removed from the upper body by positive pressure.

[Text] Prolonged exposure of people to water immersion, which simulates low gravity, is associated with changes in basic parameters of central and peripheral hemodynamics [1, 2, 8]. In recent years, studies have been pursued of the effect of diminished gravity on hemodynamics of individuals with borderline arterial hypertension (BH). This was done because of the possible participation in spaceflights of individuals over 40-45 years old [3, 9, 14]. At the same time, it is still a pressing task to search for pathogenetically validated means of correcting circulatory disturbances. Positive pressure breathing (PPB) is one approach toward performing this task. The principles of this method have been studied rather well in both the general physiological aspect and as applied to high-altitude flights [4, 11]. However, the effects related to use of this method at low gravity have not been sufficiently investigated [5, 13]. Our objective here was to study the effect of PPB on the nature of changes in main hemodynamic parameters during 7-day immersion in water of individuals with BH.

Methods

We examined central hemodynamics in 11 individuals 45 to 51 years of age with BH. The subjects were submitted to "dry" immersion for 7 days [8]. Sessions of positive pressure breathing were administered twice a day for the first 3 days of immersion. Constant positive air pressure of 10 cm water was generated in the lungs with use of a pressure helmet and compressor. The sessions lasted 30 min.

Central hemodynamics were examined by integral rheography [7]. We calculated the following parameters: mean arterial pressure (MAP), heart rate (HR), cardiac output (CO), total peripheral resistance (TPR), strength of left ventricle (W). Blood filling of vascular regions of the head (Q_h), upper and lower lobes of the lungs (Q_{ul} and Q_{ll}) and liver (Q_l) was measured by bipolar rheography methods [10]. Rheograms were recorded using a Soviet 4RG-1 rheographic attachment and Mingograf-34 (Sweden) polygraph.

Primary processing of rheograms and statistical analysis of the results were performed by means of a programmable calculator with use of standard and special programs developed for this study. Since the parameters under study were measured many times at each stage of the study, the number of cases (n) exceeds the number of subjects.

Results and Discussion

Table 1 lists generalized data characterizing the reactions of main hemodynamic parameters to PPB during immersion. Analysis of the results indicates that immersion led to insignificant decline of MAP and increase in TPR by 6%, as compared to the baseline period. In addition, there was decline on the average from 6.88 to 6.33 ℓ/min in cardiac output ($P<0.05$) with concurrent increase in Q_{ul} and Q_{ll} (more marked for Q_{ll}; $P<0.01$). In the same period, there was reliable increase in Q_h and significant decrease in Q_l.

During the PPB sessions there was a distinct tendency toward rise of MAP with marked increase of TPR, which constituted 126% of the base level. At the same time, there was further decline of cardiac output, Q_h, Q_{ul} and Q_{ll} (decline was more marked for Q_{ul}). At the same time Q_l increased by a mean of 41% during the sessions. Thus, the liver played, under these conditions, the role of a physiological pool, collecting blood that was "pressed out" of the upper half of the body by the positive pressure [11].

Cessation of the sessions was associated with reliable change in all parameters in the opposite direction.

These results agree entirely with known data that indicate that, during immersion, along with decline of cardiac output there is substantial decrease in circulating blood volume due to centralization of blood flow and increase in stasis in the lungs [6, 12].

The changes in Q_{ul} and Q_{ll} during PPB were perhaps instrumental in normalizing ventilation-perfusion relations and diminishing intrapulmonary shunting of blood. According to the results of examining the gas composition of blood, the PPB sessions were associated with reliable elevation of pO_2 of arterialized capillary blood from 63.7±1.7 to 74.9±1.3 mm Hg ($P<0.01$).

Table 1. Changes in main hemodynamic parameters at different stages of study (in comparison to preceding stage, M±m)

Parameter	Baseline	Immersion	PPB sessions	After PPB sessions
MAP, mm Hg	90,3±3,7 (11)	−4,2±1,2** (36)	+6,0±3,0* (71)	−3,7±1,1** (32)
CO, ℓ/min	6,86±0,56 (11)	−0,53±0,31 (36)	−0,65±0,32* (71)	+0,76±0,36* (32)
HR/min	57±1,7 (11)	+1,3±1,2 (36)	+0,8±0,9 (71)	−1,7±1,1 (32)
Q_h, mℓ	0,11±0,001 (27)	+0,04±0,01** (28)	0,03±0,01* (53)	+0,02±0,01 (59)
Q_{ul}, mℓ	2,69±0,27 (20)	+0,48±0,27 (36)	−0,96±0,64 (70)	+1,63±0,6 (69)
Q_{ll}, mℓ	4,48±0,4 (21)	+2,8±0,91** (34)	−3,0±1,01** (71)	+2,4±1,1** (70)
Q_l, mℓ	1,87±0,12 (25)	−0,83±0,37* (31)	1,47±0,41** (72)	−0,59±0,41 (68)

*P<0.05.
**P<0.01 as compared to preceding stage.

Note: Here and in Table 2, n is number of measurements.

Table 2. Efficacy of PPB on parameters of central hemodynamics as a function of duration of immersion (M±m)

Parameter	Base	Immersion days					
		1		2		3	
		immers.	PPB	immers.	PPB	immers.	PPB
MAP, mm Hg	90,3±2,8 (38)	84,8±2,2 (34)	93,7±1,3** (44)	86,1±2,1 (41)	91,3±1,3* (41)	87,3±1,5 (37)	90,4±1,5 (40)
HR/min	57,6±1,7 (35)	59,7±0,8 (38)	56,6±1,0* (42)	64,8±0,8++ (30)	67,7±0,9* (41)	61,9±0,6+ (32)	66,0±1,3** (40)
CO, ℓ/min	6,86±0,56 (28)	6,18±0,26 (27)	4,99±0,22** (39)	6,76±0,31 (24)	5,8±0,25* (41)	7,07±0,35 (31)	6,21±0,26* (40)
TPR, dyne·s·cm^{-5}	1155±41 (28)	1271±61 (27)	1616±66** (39)	1265±66 (24)	1406±52 (14)	1256±58 (31)	1360±66 (40)
W, kg-m/min	8,32±0,33 (28)	6,98±0,26++ (27)	5,96±0,2** (39)	7,16±0,24++ (24)	6,28±0,25* (41)	7,92±0,28 (31)	7,01±0,21* (40)
Q_h, mℓ	0,11±0,001 (27)	0,22±0,01++ (31)	0,12±0,01** (40)	0,23±0,01++ (33)	0,14±0,01** (42)	0,25±0,01++ (24)	0,17±0,01** (40)
Q_{ul}, mℓ	2,69±0,27 (30)	5,21±0,31++ (32)	4,39±0,21* (42)	4,99±0,24++ (21)	3,21±0,19** (44)	4,96±0,12++ (25)	4,05±0,21** (44)
Q_{ll}, mℓ	4,48±0,4 (31)	8,15±0,31++ (30)	6,01±0,21** (42)	8,24±0,32++ (25)	5,93±0,11** (44)	8,19±0,3++ (30)	6,04±0,16** (44)
Q_l, mℓ	1,87±0,12 (26)	1,12±0,15++ (28)	2,28±0,13** (41)	1,52±0,19 (28)	2,37±0,17** (39)	1,17±0,22 (31)	2,35±0,19** (43)

*P<0.05.
**P<0.01. as compared to baseline.

A special analysis was performed, the results of which are listed in Table 2, in order to determine the effect of PPB as a function of its duration. As can be seen in Table 2, the changes in hemodynamic parameters presented an analogous orientation at different stages of the study. At the same time, we were impressed by the fact that the degree of change in parameters during PPB diminished gradually from the 1st to 3d day of

immersion. This function was distinctly demonstrable for MAP, CO, TPR and W. The extent of change in Q_h, Q_{ul}, Q_{ll} and Q_l remained virtually the same throughout the studied period.

The data we obtained are of definite practical interest to validation of PPB protocols. Daily use of two 30-min BBP sessions causes stabilization of Q_h, Q_{ul}, Q_{ll} and Q_l; however, it is not sufficient to elicit a long-term positive effect of redistribution of blood in a caudal direction at low gravity.

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ROENTGENOLOGICAL AND PATHOMORPHOLOGICAL CHANGES IN HEART OF DOGS SUBMITTED TO HYPOKINESIA FOR SIX MONTHS

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[Article by I. G. Krasnykh, N. A. Gaydamakin and V. G. Petrukhin]

[English abstract from source] The effect of 6-month hypokinesia on the cardiac function and pathomorphological changes in 8 dogs was investigated. The heart size during systolic and diastolic contractions, stroke volume and contractile function were measured once a month using an x-ray unit and a kymograph. After the hypokinetic exposure 6 dogs were sacrificed and their hearts were examined morphologically and histochemically. The recovery processes were investigated on 2 other dogs that were allowed to survive for 30 days after exposure. The 6-month hypokinesia led to a significant decrease in the heart size, stroke volume, cardiac index and the contractile function. Postmortem morphological examinations revealed atrophic changes in the myocardium. Electron-microscopy investigations demonstrated focal destructive changes in myofibers and in mitochondria: some of them were dense while others had a more transparent matrix and degraded cristae. Histochemical data (increased acid and alkaline phosphatase) also suggested atrophic and destructive changes in the myocardium. The above changes did not return to normal within 30 days of the recovery period.

[Text] Prolonged hypokinesia is one of the causes of rise in incidence of cardiovascular disease. It is important, in both clinical and theoretical aspects, to investigate functional and morphological changes in the heart during long-term restriction of movement, since this makes it possible to outline the means of prevention and development of more effective methods of treating cardiovascular pathology [2, 6, 7, 10-13]. This study deals with the effect of long-term hypokinesia on cardiac function and nature of pathomorphological changes in the myocardium.

Methods

In the experiments, we used 8 dogs of both sexes, 3-5 years of age, which were restricted in their movements for 6 months. To produce hypokinesia

we used cages with movable front and top sides [3], which enabled us to adjust the size of the cage according to the dog's size. The animal could lie on its abdomen in the cage or on either side and consume feed in these positions. There were drain holes in the bottom of the cages. The animals were moved once every 10 days into thoroughly washed, clean cages of the appropriate size. In addition, we used three dogs as a control. We determined the volume of the heart in systole and diastole, as well as myocardial contractility twice before the experiment, then on the 15th and 30th days, and monthly thereafter, on roentgenokymograms. A pathomorphological examination was performed on six dogs after sacrificing them with a mixture of ether and chloroform immediately after the hypokinetic period in order to demonstrate minute structural and biochemical changes in the myocardium. To examine recovery processes, 2 dogs were sacrificed 30 days after hypokinesia. Samples of myocardial tissue from the left and right ventricles were fixed in 10% neutral formalin or Carnoy fluid and imbedded in paraffin. Deparaffinated sections were stained according to Van Gieson and with resorcin-fuchsin after Weigert. For histochemical studies, pieces of ventricular wall tissue taken from experimental and control groups of animals were mounted on the same tray forming a so-called combined block of tissue [8]. On combined sections cut in a cryostat from these fresh-frozen tissue blocks, we demonstrated neutral lipids with scarlet red, glycogen after Shabadash; we determined the activity of monoamine oxidase, acid and alkaline phosphatases, succinate dehydrogenase, α-glycerophosphate, NAD H_2, glutamate, inosine-5-phosphate [9] and dihydroorotate [4, 5]. For electron microscopy, pieces of myocardium were fixed in a solution of glutaraldehyde and then in a mixture of osmium tetroxide and potassium bichromate by the method in [1]. The material was imbedded in epon-812. Semithin sections were stained with polychrome blue after Unna and a site for examination was targeted. Ultrathin sections were prepared on an LKB-4804 ultratome, contrasted with uranyl acetate and lead citrate according to Reynolds, then examined under a JEM-7 electron microscope.

Results and Discussion

Hypokinesia for 15 days was associated with reduction of heart volume in systole and diastole by a mean of 10% (see Table). By the end of the 30th day, the difference from the base value was 15% and after 60 days, 20%. For the next 4 months, this parameter remained at a low level with minor fluctuations. As can be seen from the Table, an analogous pattern was noted in determining stroke volume, the only difference being that the decline of this parameter was twice as marked as the decrease in heart size. By the end of the 2d month, stroke volume was 35% lower than initially and by the end of the 4th and 5th months, 40% lower. There was also decline of heart index, particularly in the first 2 months. The changes in these parameters were associated with appearance of signs indicative of diminished contractile function of the myocardium: on both outlines of the heart the roentgenokymographic waves were shorter and their number in one band increased. With increase in duration of hypokinesia these changes became more marked (Figure 1).

Only about 50% of the lost heart size and stroke volume was recovered by dogs that were kept for 30 days under ordinary conditions after hypokinesia. Myocardial contractility was also only 50% restored.

Effect of hypokinesia on heart size and cardiac index of dogs

Duration of hypokinesia, days	Heart size, cm^3		Stroke volume	Cardiac index
	systole	diastole		
0,5	134,0±6,8 (--8,2)	146,0±6,5 (—9,3)	6,0±0,5 (--15,5)	—
1	128,0±9,0 (--12,3)	138,0±8,8 (—14,3)	4,9±0,3 (—31,0)	11,1±0,6 (--7,5)
2	120,0±9,5 (—17,8)	120,0±9,9 (--19,9)	5,6±0,3 (--35,2)	10,6±0,5 (—11,7)
3	118,0±9,6 (--19,2)	127,0±9,9 (--21,1)	4,4±0,19 (--38,0)	10,6±0,6 (--11,7)
4	117,0±8,5 (--19,9)	125,0±8,4 (--22,3)	4,2±0,2 (--40,8)	10,6±0,5 (--11,7)
5	118,0±9,5 (--19,2)	127,0±9,7 (--21,1)	4,2±0,2 (--40,8)	10,9±0,6 (--9,2)
6	116,0±6,7 (--20,6)	125,0±8,1 (--22,4)	4,5+0,28 (—36,6)	10,8±0,7 (--10,0)
Baseline data	146,0±11,4	161,0±11,3	7,1±0,4	12,0±0,8

Note: Decline of parameter from base value (%) and cardiac index--ratio of heart volume (in cm^3) to body weight (kg)--given in parentheses.

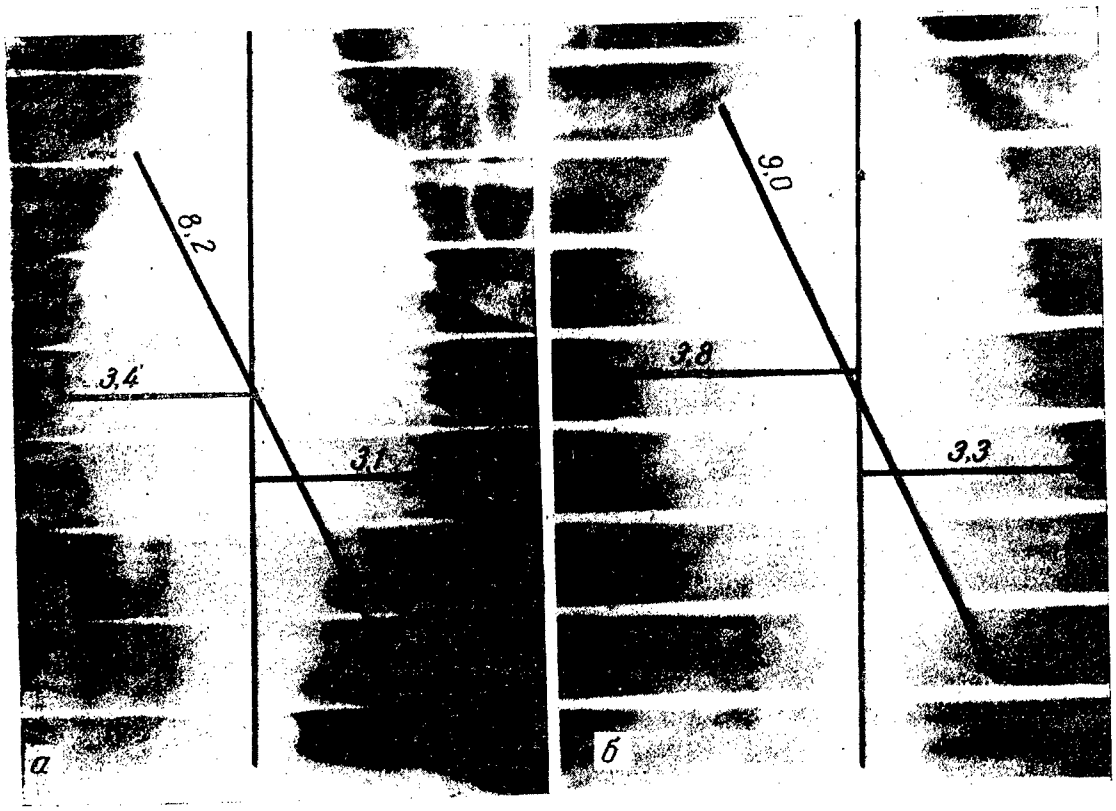

Figure 1. X-ray of dog's heart

a) after 6-month hypokinesia b) baseline

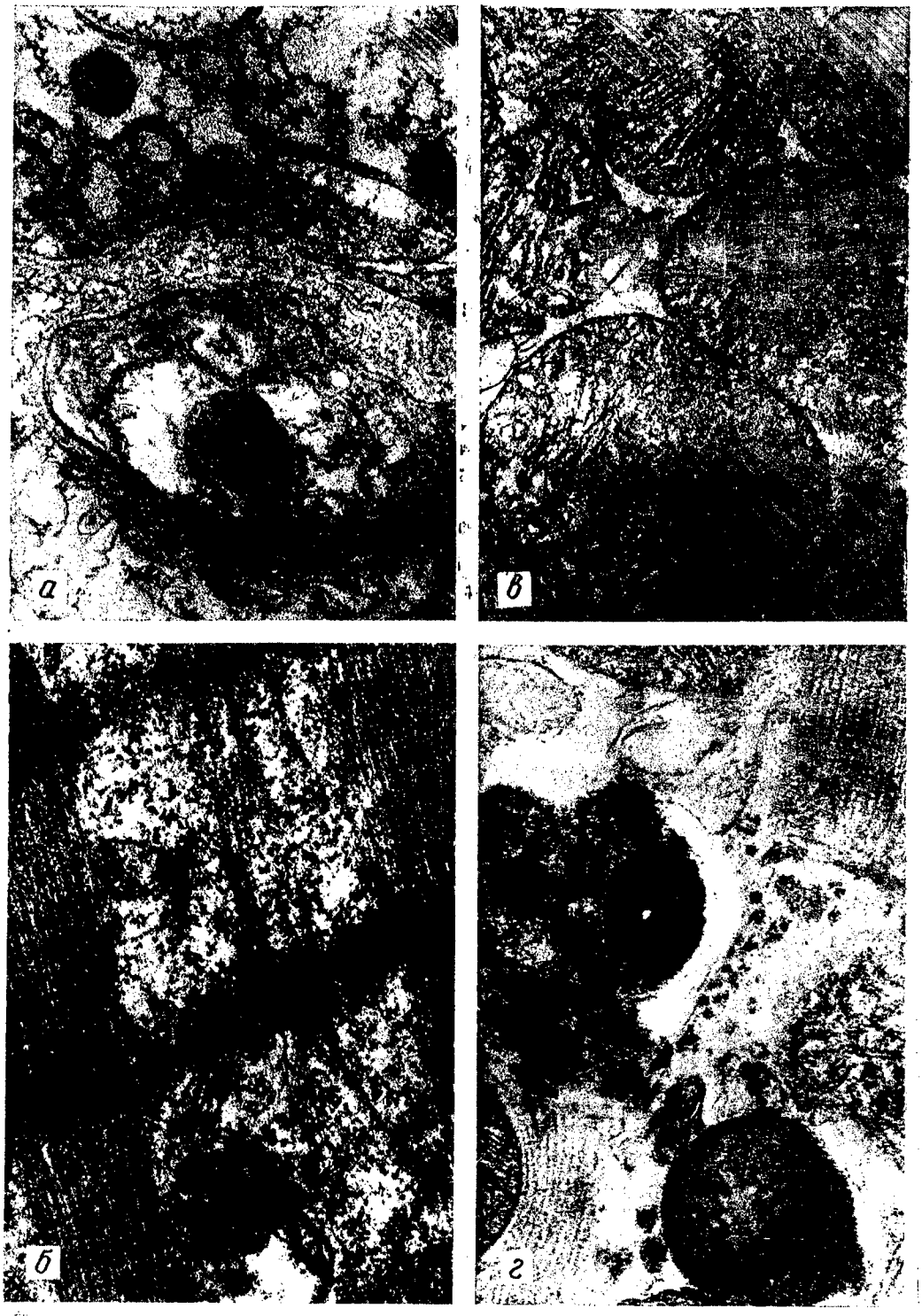

Figure 2. Electronogram of dog's heart after 6-month hypokinesia

а and *в*) left ventricle; magnification 32,000 and 27,000×, respectively
б and *г*) right ventricle; magnification 35,000 and 45,000×, respectively

Microscopic examination of the myocardium revealed some narrowing of the lumen of blood vessels. There was increased activity of monoamine oxidase, acid and alkaline phosphatases in the walls of vessels, particularly arteries. Myocyte nuclei in the wall of the left ventricle were elongated, tortuous and had pointed poles; they were somewhat hyperchromic. On cross section, the shape of the nuclei was notable for significant polymorphism: it had the appearance of hooks, commas and triangles. Next to the nuclear poles there was material in the form of large clumbs resembling lipofuchsin granules, which separated the contractile elements of cells. Activity of succinate, α-glycerophosphate dehydrogenases, NAD•H_2, glutamate, dihydroorotate and inosine-5-phosphate diminished; that of monoamine oxidase, alkaline and acid phosphatases increased. There was an increase in glycogen content under the epicardium and endocardium.

Changes of the same kind developed in the wall of the right ventricle, but they were less marked than in the left ventricular wall. Many myocyte nuclei had a normal appearance, others had a larger cross section and dull, rounded poles which imparted the appearance of a triangle. The karyoplasm of such nuclei was clear. Activity of most enzymes diminished, with the exception of α-glycerophosphate dehydrogenase and monoamine oxidase, the change in activity of which was indistinct, as compared to the control.

Electron microscopy of the myocardium revealed increase in activity of capillary endothelium: on the internal surface of endotheliocytes there were many microfibrils, folds that protruded far into the vascular lumen; numerous pinocytotic blebs, phagosomes and vacuoles were visible in the cytoplasm of endotheliocytes (Figure 2*а*). Mitochondria had a cleared matrix and their cristae were partially destroyed. The basal layer of capillaries was friable and thickened.

In myocytes, there was prevalence of destructive changes, particularly in the left ventricular walls. Some segments of the myofibrils were homogenized or had undergone dissociation within the limits of one or several adjacent sarcomeres. The Z bands remained unchanged (Figure 2*б*). Mitochondria underwent appreciable changes. Most of them had a flattened matrix and were wanting in a considerable number of cristae. We also encountered mitochondria with clear matrix and shortened cristae (Figure 2*в*). Some mitochondria had undergone breakdown, changing into clear vacuoles containing myelinoid bodies instead of cristae. There was accumulation of lipofuchsin (Figure 2*г*) between myofibrils (mostly in the perinuclear region). T-system cisternae were reduced, with consolidated lumen.

Along with destructive changes in the wall of the right ventricle, we could detect changes inherent in an increased functional load: mitochondria with distinct internal structure and cleared matrix, myofibrils with fewer sites of disintegration.

Animals sacrificed 30 days after hypokinesia and maintained for this time under conditions of normal mobility presented only partial recovery from the structural changes.

It is noteworthy that development of the changes demonstrable on roentgenokymograms was intensive for the first 3 months of the experiment. The next 3 months of hypokinesia were associated with only insignificant further decline of the cardiac parameters studied. The cardiac changes found by x-ray techniques were corroborated by the results of pathomorphological

examination of the myocardium. A histochemical parameter, such as increase in acid and alkaline phosphatase activity was indicative of atrophic and focal destructive changes in the myocardium. The decrease in activity of redox enzymes indicates that weakening of myocardial contractility is related to drastic decrease in energy-forming processes. The decrease in activity of dihydroorotate and inosine-5-phosphate dehydrogenases means that synthesis of metabolites involved in production of nucleic acids is diminished. Thirty-day adaptation was not sufficient to eliminate all the adverse effects that developed in the myocardium under hypokinetic conditions. There was only 50% restoration of impaired cardiac function in this time. Some atrophic changes were still demonstrable in the myocardium 30 days after hypokinesia; the activity of several redox enzymes remained low.

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CHANGES IN PHYSICAL CONDITION, VESTIBULAR FUNCTION AND BONE SYSTEM OF RATS SUBMITTED TO LONG-TERM ROTATION

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[Article by A. A. Shipov, V. N. Shvets, L. A. Tabakova and O. Ye. Kabitskaya]

[English abstract from source] The unrestrained rats were rotated for 21 and 30 days at 1.1 and 2.0 G. The exposure did not deteriorate their equilibrium function or physical condition, i.e., static and dynamic endurance. However, the exposure decreased the reactivity and sensitivity of the semicircular canals. Bone parameters--longitudinal and transverse bone growth, metaepiphysis morphometry--indicated that the rats developed an acute stress reaction accompanied by an inhibited growth of limb bones during the first 7 days of rotation. By experimental day 30 the animals became adapted to the new environment.

[Text] In the future, elimination of the weightlessness factor by means of artificial gravity (AG) produced by rotating the spacecraft will be a radical means of controlling the adverse effects on man of long-term zero gravity [13]. The biomedical aspects of AG are determined by physical and physiological effects that arise in a rotating system, and they are related to the need for medical support of human life under such conditions. An extensive set of studies must be pursued during spaceflights and on the ground, with participation of man and animals, in order to solve biomedical problems of AG [4].

Ground-based experiments on animals make it possible to conduct studies that would either be impossible with the participation of man or would require major expense. In particular, the duration of rotation of animals in relation to life span can be immeasurably longer than for man, while the use of small animals permits demonstration of statistically reliable changes in physiological functions in a single experiment.

The results of the study conducted aboard Cosmos-936 biosatellite with onboard AG revealed that laboratory rats are a convenient object for solving a number of AG problems [1].

Our objective here was to study the changes in static and dynamic endurance, as well as vestibular function, during and after long-term rotation, to assess the effect of rotation on equilibrium function and conduct a morphometric study of skeletal bones of rats kept in unrestricted groups at different levels of gravity.

Methods

We conducted four series of experiments. Each experiment in the first 3 series was performed on 30 male mongrel white rats weighing 155-200 g. The animals were divided into three equal groups that did not differ reliably in average weight: animals of the central (C) and peripheral (P) groups were kept in containers on a centrifuge (Figure 1) and the control group (K) in an ordinary cage. Centrifuge rotation rate was 33.3 r/min, gravity constituting 2.0 G in the peripheral containers (radius 141 cm) and 1.1 G on the perimeter of the central containers (radius 41 cm).

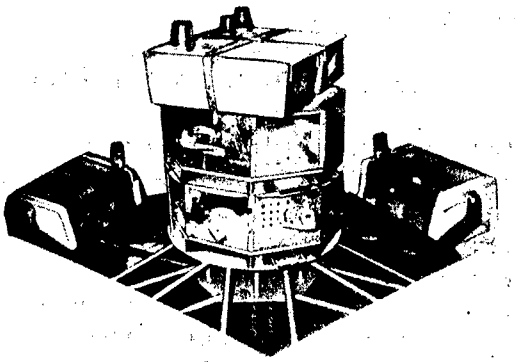

Figure 1.
Centrifuge for prolonged rotation of animals. Two of the six peripheral containers and three central containers can be seen

All of the rats were kept in the same room on a similar diet with a 12:12 ratio between light and dark periods. The centrifuge was stopped for 1 h daily, at the same time of day, and during this time the animals were weighed, cages were cleaned, feeders and water bottles were refilled. On some days, the animals were examined during this hour.

In the experiments, we tested the effect of 21-day rotation on static endurance (1st series), dynamic endurance (2d series), vestibular function and equilibrium (3d series). In the 4th series, we tested the effect of 30-day rotation on morphometric parameters of bones.

Static endurance was assessed on the basis of maximum time that the animals could stay on a rod [10].

Maximum swimming time with a weight constituting 20% of the animal's weight, in a tank with water at 33-36°C, served as the parameter of dynamic endurance. The weight, in the form of a lead plate, was secured on the animal's belly with a rubber strap.

Vestibular function was evaluated by the changes in characteristics of nystagmic reaction to angular acceleration of $30°/s^2$ [11]. Nystagmus was graded by its latency period, number of beats, duration and mean frequency.

Equilibrium function was assessed clinically, observing the animal's behavior on an inclined plane (length 120 cm, width 5 cm, angle of inclination 12°), as well as on rectangular (width 3 cm, length 50 cm) and conical (maximum

diameter 3 cm, length 50 cm) beams placed horizontally 30 cm above the surface of the table.

The animals were examined 10-14 days before rotation (baseline), during rotation (static endurance on 4th, 7th and 14th days; dynamic endurance on 5th, 8th and 15th days; nystagmic reflex on 2d, 6th and 13th days) and in the aftereffect period (static endurance on 3d, 6th, 14th and 19th days; dynamic on 4th, 7th, 15th and 20th days; nystagmic reflex on 1st, 4th, 7th, 14th and 22d days; equilibrium on 1st, 4th, 7th, 14th and 22d days). We considered the day on which rotation stopped (21st day) as day 0 of the aftereffect period.

After completion of experiments in the first 3 series, we performed several series of additional control experiments on 170 animals to gain more information and verify some of the results. In these experiments, we examined changes in static endurance after 3-, 7- and 11-day rotation of animals kept unrestricted and in hypokinetic cages, 11-day rotation in box-cages where single unrestricted animals were kept [9], with 21-day rotation in hypokinetic cages (to define the nature of the curve, changes in static endurance, effects of restricting movement). During 21-day rotation of unrestricted animals, we monitored the behavior of animals in the second group submitted to labyrinthectomy* (role of vestibular system in behavioral reactions), as well as the behavior of intact animals rotated in the centrifuge at 50 r/min (effect of gravity level on behavioral reactions). In addition, we tested the effect of 21-day rotation on tolerance of 2d group animals to +Gz accelerations (additional indicator of physical condition). The reaction to accelerations was assessed mainly according to changes on the ECG (heart rate) during exposure to head-pelvis accelerations of 5 G for 3 min (probability of death 0% in background period) on a centrifuge with a 4-m arm. The gradient of build-up of accelerations and braking was 0.16 units/s.

The 4th series of experiments was conducted on 2-month-old male Wistar SPF rats.

We decapitated 8 animals before starting the experiment (baseline control), 8 animals on the 7th and 22d days of rotation and 7 animals each from the K, C and P groups on the 30th day. After decapitation, we isolated the femur and tibia, measured their length with calipers, then placed them in a mixture of 5% formalin and Muller's fluid. The bones were then decalcified in 5% nitric acid and submitted to histological treatment. To assess bone growth in width, we measured the area of the cross section, cortical plate and bone marrow canal of the diaphysis of the tibia and humerus. For this purpose, we prepared 20-μm sections on a freezing microtome, outlined with a photo enlarger the projection, and the outline was subsequently submitted to planimetry. For morphometry of the epiphyseal growth plate and volume of metaphyseal spongiosa, we prepared 5-7- μm paraffin sections and stained them with hematoxylin and eosin.

The experimental material obtained was submitted to statistical processing with use of Student's criterion ($P<0.05$).

*A. V. Mokrousova performed delabyrinthectomy by the electrocoagulation method [5].

Results and Discussion

Animals' general condition and behavior. In the first minutes of rotation of the centrifuge group C animals started to move rapidly counter to the direction of rotation, often changing to a run. Their movements slowed down and stopped after 8-10 min. They remained near the walls along the perimeter of the container so that the resultant centrifugal force and gravity were directed from the back to the chest. Analogous observations had been described previously [3]. For the next 2-3 days the animals moved little, spending most of the time near the container walls. On the 3d-4th day of rotation, the animals' behavior became more active, they began to move over the entire container in different directions, but their coordination was somewhat labored. On the following days, the rats' motor activity continued to increase (particularly at night), reaching a maximum on the 7th-8th day, after which it began to decline. By the 15th-16th day, the behavior of animals in the C group did not differ from that of the K group. By this time, the rats had adapted entirely to their living conditions in a rotating system, they moved readily and easily in any direction. Observation of animals during rotation at 50 r/min (1.4 G along the perimeter of the central container) revealed that, in this case, the animals preferred to remain in the center, rather than the walls, of the container during 21-day rotation. Hence, 1.4 G gravity is "unpleasant" for rats.

The P group of animals also presented increased motor activity during the first minutes of rotation, then remained near the posterior (in the direction of rotation) wall of the container. Starting on the 2d-3d day, the animals were located in the most varied parts of the container without visible preference for any particular places. On the whole, motor activity of group P animals was lower throughout rotation than in group C. Observations of labyrinthectomied animals during 21-day rotation revealed that they preferred the anterior wall (in the direction of rotation) of the container on the 1st day, and on subsequent days they were in different places. Motor activity of labyrinthectomied animals was higher from the 1st day of rotation than that of intact ones; it changed little in the course of rotation and did not differ from activity of labyrinthectomied animals in the K group. These findings indicate that the motor activity of intact animals in a rotating system is largely determined by the functional distinctions of the vestibular apparatus in this system. G. I. Gorgiladze arrived at the same conclusion in a comparison of the behavior of intact and labyrinthectomied animals in a revolving spiral maze [2].

Observation of rats during the daily stops of the centrifuge failed to reveal appreciable differences in condition or behavior of group K and C animals. At the same time, group P was notable for some inhibition of reactions. For the first 3-4 days of rotation they were inactive and their fur was ruffled.

Equilibrium. We failed to demonstrate differences in behavior between C, K and P animals on a slanted surface, rectangular or conical beams.

The dynamics of the animals' weight during rotation and in the aftereffect period are illustrated in Figure 2A. As can be seen in this figure, there is weight loss in the 1st week of rotation, as compared to the baseline (more marked in P group animals), after which this parameter begins to rise,

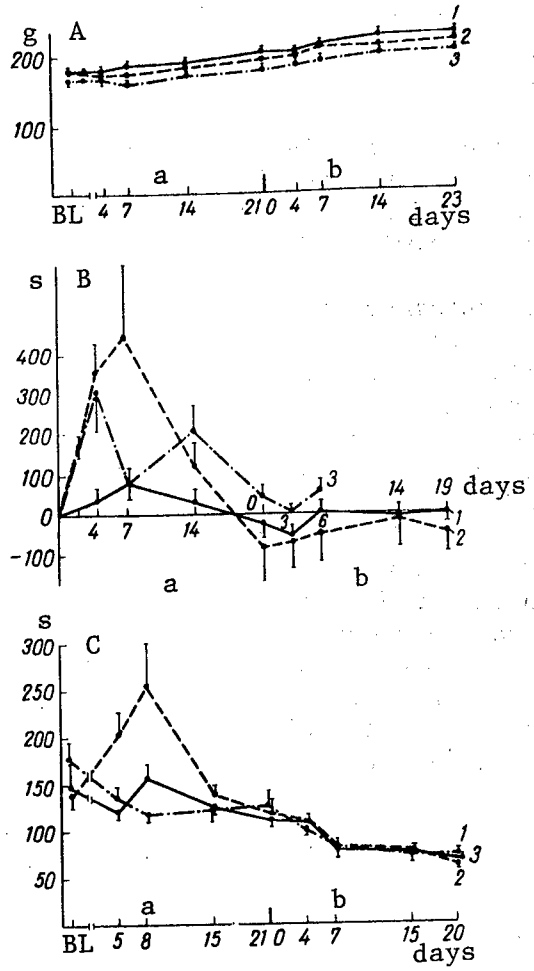

Figure 2.
Dynamics of weight (A), static (B) and dynamic (C) endurance of rats during 21-day rotation and in aftereffect period
X-axis, day of examination;
y-axis:
A) weight (g)
B) change in duration of holding on to rod, as compared to baseline (BL)(in seconds)
C) maximum swimming time with weight (s)
Here and in Figure 3:
1, 2, 3) groups K, C and P, respectively
a) during rotation
b) after rotation

but more slowly than in group K animals. The lag in weight gain of rotating animals, including those exposed to close to 1 G gravity, has been observed by all researchers who studied animal reactions to long-term rotation, but the mechanisms involved in this consistent weight loss have still not been identified [8].

Physical endurance. In C group animals, both parameters of physical endurance increased reliably during the 1st week of rotation, as compared to both baseline values and those inherent in group K animals. They reached a maximum on the 7th-8th day, then dropped to baseline values by the 14th-15th day (Figure 2B and C). Analogous changes in endurance were less distinctly evident in group P animals. On subsequent days of rotation, as well as in the aftereffect period, there were no differences in parameters of static and dynamic endurance of animals in groups K, C and P, although the latter group presented a mild tendency toward increase in static endurance, as compared to groups K and C.

It should be noted that static endurance of groups C and P animals was reliably higher than group K in the additional series of control experiments after rotation for 3 and 7 days, but after 11-day rotation no reliable differences in these parameters were demonstrable. At the same time, no increase in static endurance was noted after 3- and 7-day rotation of analogous duration in hypokinetic cages. Nor was such increase observed in the course of 21-day rotation in hypokinetic cages. Such transient increase in parameters of physical endurance of rats during 21-day rotation when they were kept in unrestricted groups is apparently related to the noted changes in motor activity which, in turn, could have been due to the animals' stress reaction to unusual living conditions.

After rotation, we found no differences between reactions of K and C groups of animals to +Gz acceleration according to the criterion of heart rate. It

should be noted that A. A. Gyurdzhian et al. [3] previously failed to find differences in tolerance to lethal accelerations in rotated and control animals.

Thus, 21-day exposure of rats to rotation at gravity levels of 1.1 and 2G when kept in unrestricted groups did not lead to worsening of equilibrium or physical condition (according to parameters of static and dynamic endurance), as compared to the findings inherent in group K animals.

Vestibular function. Examination of the nystagmus reaction of group K animals revealed smooth decrease in number of beats, duration and mean frequency of nystagmus from examination to examination (Figure 3), which was indicative of development of habituation to repeated exposure to angular accelerations. There was virtually no change in latency period of nystagmus. For rotated animals in groups C and P other dynamics of nystagmus parameters were present. The number of beats, duration and mean frequency of nystagmus in these animals diminished to one-half by the 2d day of rotation, as compared to baseline values and those inherent in group K animals (see Figure 3). On subsequent examination days there was insignificant decline of parameters. The latency period of nystagmus was longer than in group K. Such changes in parameters of nystagmus upon re-examination of groups C and P is indicative of development of habituation to angular accelerations already in the course of exposure to the rotating system due to periodic stimulation of receptors of semicircular canals by precession accelerations [7], which arise upon displacement or movement of the head.

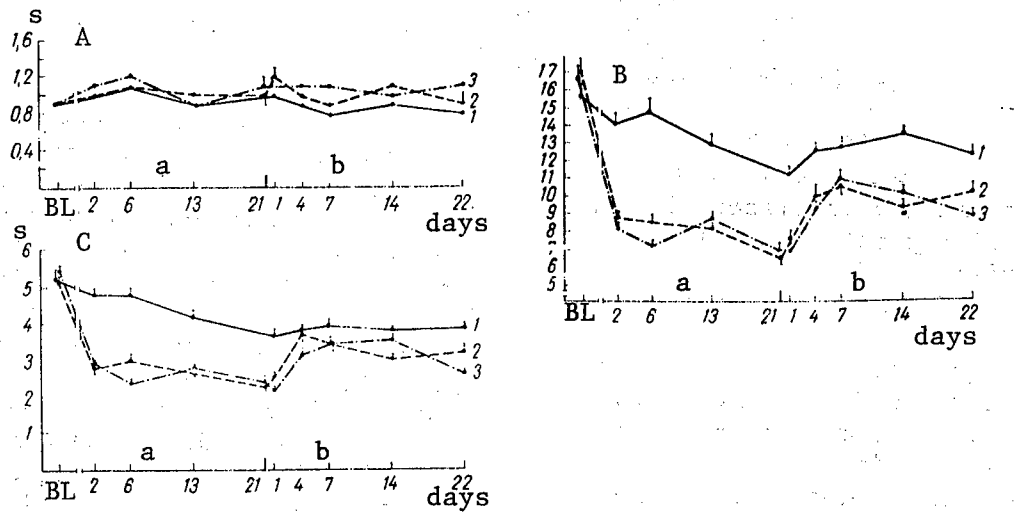

Figure 3. Dynamics of latency period (A, in s), number of beats (B) and duration (C, s) of nystagmus in rats during 21-day rotation (a) and in the aftereffect period (b). X-axis, day of examination; angular acceleration 30°/s; BL--baseline

The changes in nystagmic reaction in the aftereffect period following 21-day rotation did not differ from those we observed previously during preparations and performance of experiments aboard Cosmos-936 biosatellite [6, 12]. They

consisted of the following. The latency period of nystagmus was longer in groups C and P animals throughout the study period than in group K. The number of beats was drastically reduced on the day of termination of rotation, as compared to both baseline values and the level inherent in group K. Subsequent examinations (4th-7th days) revealed reliable increase of this parameter, as compared to the value recorded on 0 day, followed by a distinct tendency toward decline. However, even on the 22d day of the aftereffect period, the number of beats was increased, as compared to 0 day. In all of the examinations, the number of beats was lower for groups C and P animals than group K. Analogous patterns were inherent in the curve of duration of nystagmus (see Figure 3). The curve of dynamics of mean frequency presented merely a tendency toward such changes. Such typical changes in parameters of the nystagmic reaction upon re-examination of animals in groups C and P in the aftereffect period following long-term rotation indicate the onset of complex residual processes in the nystagmic center of the central nervous system due to prolonged stimulation of receptors of semicircular canals by precession accelerations, in the presence of additional stimulation of otoliths by the hypergravity during stay in rotating system [12].

Thus, with 21-day rotation at 1.1 and 2 G, the rats present decrease in sensitivity and reactivity of the vestibular system to angular accelerations.

On the first days of rotation and the aftereffect period, the number of beats, duration and frequency of nystagmus were somewhat lower (though unreliably) in group P animals than in group C. This tendency of change in parameters of the nystagmic reaction, which had also been observed in the experiment aboard Cosmos-936 [12], is most probably due to the effect of hypergravity on the otolith system [15].

These results convincingly show that, with 21-day stay in a rotating system in unrestricted groups, the physical condition and equilibrium of rats do not worsen, i.e., under these conditions rotation factors do not have an adverse effect on these parameters. It can be assumed that the physical condition of man, as well as equilibrium, will not worsen after spending a similar time (1/50th of life span) in a rotating system, and vestibular reactions will diminish in the course of rotation; the higher the level of gravity, the more marked this decline will be.

Lengthwise bone growth. A mild tendency toward lag in lengthwise growth of the femur was observed in groups C and P animals on the 18th-19th day of rotation, as compared to group K. The differences from the control at this time constituted less than 5% for the tibia and humerus. Similar results had been obtained previously on young rats submitted to rotation for 18 days at 2 G gravity [17].

It is known that inhibition of lengthwise bone growth is particularly distinct at higher levels of gravity and with longer exposure. In the opinion of most researchers, hypergravity retards lengthwise bone growth and imparts a more massive shape to it: the bone becomes shorter, thicker and more compact [20, 21], which leads to increase in its strength [16, 22].

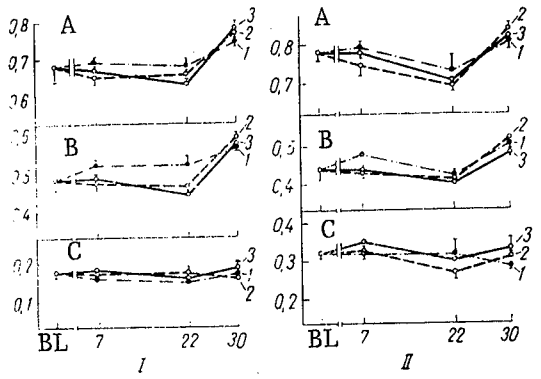

Figure 4.
Area of cross section (A), cortical plate (B) and medullary canal (C) of tibia (I) and humerus (II) of rats during 30-day rotation
X-axis, day of rotation; y-axes, area (in arbitrary planimetric units). BL--baseline

Bone growth in width. The area of the cortical plate of the tibia and, particularly, the humerus of group P animals decreased with statistical reliability, as compared to group K animals, only on the 7th day of rotation (Figure 4). When rotation was continued, this parameter reverted to the level for group K animals. In group C rats, an analogous pattern of changes was observed in the form of a tendency. The area of the medullary canal did not change appreciably at any stage of the study in groups C and P animals, as compared to group K.

Thus, the parameters chosen to assess rat bone growth in width are indicative primarily of the fact that the rate of appositional (or periosteal) bone growth in the anterior and posterior extremities is significantly inhibited only at the early (7th day) stages of rotation, whereas by the 30th day of rotation bone growth is restored to the control level. No basic differences were demonstrable in rate of bone growth in width between groups C and P animals.

It is difficult to compare our findings to data in the literature, since there have been few studies of the area of cross section of bones in animals exposed to hypergravity, and they are contradictory due to use by authors of different species of animals and levels of accelerations. It was shown that, at 2.76 G, there was a reduction of cross section of the diaphysis and medullary cavity of the femur in rats rotated for over 2 years [14, 21].

The demonstrated inhibition of appositional bone growth in groups C and P rats on the 7th day of rotation and its normalization by the 30th day is of considerable interest. The area of the medullary canal remained on the control level at all examination times, which is indicative of absence of endosteal resorption. This circumstance suggests that the delay in rate of periosteal osteogenesis is unrelated to change in level of parathyroid hormone, if it did occur under the effect of hypergravity. This assumption is confirmed by the absence of osteocytic lysis (as a reaction to hyperparathyroidism) in the cortical bone of rats submitted to rotation for 18 days at 2 G [17]. Perhaps, inhibition of bone growth in width, which was noted on the 7th day of rotation in groups C and P rats, is attributable to development of a stress reaction. It is known that corticosteroid hormones affect bone metabolism and particularly some bone structures such as the epiphyseal growth plate [18, 19]. With such a (stressor) mechanism, one can expect a reduction in width of the epiphyseal growth plate on the 7th day of rotation and normalization of this parameter by the 30th day of rotation. Indeed, as can be seen in the Table, the width of the epiphyseal growth plate diminished with statistical reliability on the 7th day of rotation in groups C and P animals. Of course, such a reaction of the growth plate led to reduction in volume of primary and secondary spongiosa. At the same time, these changes disappeared on the

Parameters of rat tibial metaphysis at different stages of rotation

Animal group	Day of rotation	Width of epiphyseal growth plate, mm	Relative volume of spongiosa %
K	7	1,265±0,0255	29,12±3,10
C	7	0,942±0,0145*	20,65±2,10*
P	7	0,896±0,0385*	18,20±2,25*
K	22	1,056±0,023	15,45±1,38
C	22	1,013±0,018	16,60±1,14
P	22	0,995±0,019	16,30±0,40
K	30	1,060±0,041	19,52±2,48
C	30	0,986±0,064	14,16±1,30
P	30	0,940±0,025	16,86±0,43

*P<0.05, as compared to parameters for K group.

22d and 30th days of rotation. It can be assumed that adaptation to rotating conditions had occurred by this time. Consequently, the hypothesis that inhibition of appositional growth and some lag of lengthwise bone growth demonstrated at the start of rotation are due to a stress reaction is valid.

Thus, analysis of data on condition of rat bone using such integral parameters as bone growth in length and width, morphometry of metaepiphysis enables us to conclude that rats kept for 30 days in a rotating system in unrestricted groups develop adaptation to unusual living conditions. Apparently, adaptation begins after the 7th day of rotation. Up to that time, there is probably development of an acute stress reaction, which is associated with moderate inhibition of rate of growth of limb bones. The specific effect on bone of accelerations perhaps occurs with longer rotation. It is important to stress that no pathological processes develop in rat skeletal bones in the course of 30-day rotation at 1.1 and 2 G.

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CONTRACTILE PROPERTIES OF RAT MUSCLE FIBERS DURING LONG-TERM EXPOSURE TO +2 Gx ACCELERATIONS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 19, No 5, Sep-Oct 85 (manuscript received 2 Jul 84) pp 53-56

[Article by V. S. Oganov, S. A. Skuratova and M. A. Shirvinskaya]

[English abstract from source] The effect of 21-day exposure to +2 Gx and +1.1 Gx on the contractile properties of different muscle groups of rat fore- and hind-limbs was examined, using glycerinated myofibers in the ATP+Ca^{2+} solution. It was found that the isometric contraction strength and velocity increased, the performance of the postural extensors also grew: that of the soleus m. in the +2 Gx rats and that of the triceps brachii m. in the +2 Gx and +1.1 Gx rats. The contractile changes of the flexors of fore- and hindlimbs were insignificant and sometimes oppositely directed. The different responses of the muscles to acceleration were associated with the differences in their function, metabolism and biomechanics.

[Text] The principle of mutual supplementation of studies on the effects of weightlessness and long-term accelerations has gained recognition in gravity physiology [1, 17]. According to the theses of K. E. Tsiolkovskiy, the effects of accelerations or artificial gravity (AG) are viewed as a means of preventing the undesirable sequelae of weightlessness [3], including those referable to the mammalian skeletomuscular system.

Experience in the study of AG effects on preparations of isolated muscles and muscle fibers confirmed the benefit of such combined research to biomechanical analysis of mechanisms of effects of weightlessness on mammalian skeletal muscles [8]. The study reported here, which was ultimately aimed at solving this problem, pertains to the effect of long-term exposure to accelerations on contractile properties of fibers of functionally differentiated skeletal muscles.

Methods

This study is part of a combined experiment with long-term (21 days) centrifugation of rats, the conditions of which were described before [4].* The

*We wish to express our appreciation to A. R. Kotovskaya and A. A. Shipov, who organized the experiment, for granting us the opportunity to conduct this study.

animals were divided into three groups. Animals of one experimental group were placed on the end of a centrifuge arm and exposed to +2 Gx accelerations (periphery--P); rats in the second group were in the center of rotation (center--C) and were exposed to +1.1 Gx accelerations. The control group of animals (K) was kept under vivarium conditions. Upon termination of the experiment, after decapitating the animals, we isolated and made preparations of glycerin-treated muscle fibers from the hindleg--soleus (SM), long digital extensor (LDE)--and foreleg--medial head of the brachial triceps (MHBT) and brachial (BM) muscle. We used the method of Szent-Gyorgyi [18] in our modification [10]. We examined the characteristics of ATP+Ca^{2+}-induced contraction of muscle fiber preparations (up to 20 in each muscle)--amplitude, velocity, work capacity--and the obtained data were submitted to statistical analysis using the criterion of Student.

Results and Discussion

We demonstrated a distinct tendency toward increase in absolute mass of MHBT in group P animals ($P<0.05$) and absence of changes in SM mass in both groups of rats (Table 1). There was more noticeable, but statistically unreliable, increase in relative mass of both antigravity muscles in both experimental groups. In rapid muscles (LDE, BM), the changes in absolute mass were in the opposite direction in both experimental groups, whereas relative mass did not change (see Table 1). A statistically reliable reduction of body weight was demonstrated in both experimental groups of animals. Biometric studies revealed a tendency toward decrease in diameter of fibers in fast muscles and increase in MHBT, which was consistent with these data.

Table 1.
Rat muscle mass after 21-day exposure to accelerations (M±m)

Muscle	Animal group		
	P	C	K
SM	115,96±11,04	120,20±9,02	118,20±6,30
LDE	122,29±8,28	125,20±7,28	134,20±9,70
MHBT	144,0±7,52*	145,20±12,46	122,40±9,09
BM	119,29±11,48	148,40±9,41	167,60±6,98

*Here and in Tables 2 and 3, the differences are reliable with probability of at least 95%.

Maximum amplitude (P_M) of ATP+Ca^{2+}-induced isometric contraction of fibers was increased with statistical reliability in MHBT and SM preparations from group P animals (an analogous tendency was also observed in group C). Work capacity of fibers of these muscles, as determined from the value for strength impulse, was also increased ($P<0.05$ only for MHBT of both experimental groups of animals) (Table 2). As can be seen in Table 2, this was associated with minor change in strength of contraction of fast muscles, and it had a tendency toward increasing in group P animals, whereas the work capacity of these muscles diminished insignificantly and statistically unreliably in both experimental groups of animals.

The velocity of development of isometric contraction (in the linear segment of the mechanogram in the P_M range of 0.2-0.6) increased with statistical reliability in preparations of fibers of postural muscles, and for MHBT preparations this was noted in both experimental groups (Table 3). In contrast, there was a tendency toward slowing of the process of development of contraction in LDE preparations.

Table 2.
Isometric contraction (exertion, in $H \cdot mm^2 \times 10^{-2}$) and strength impulse (in $H \cdot s \cdot 10^{-1}$) of rat muscle fibers after 21-day exposure to accelerations

Muscle	Animal group		
	P	C	K
	Exertion ($H \cdot mm^2 \cdot 10^{-2}$)		
SM	49,42±3,69*	36,55±3,50	32,71±1,92
LDE	52,23±4,96	42,72±4,95	42,97±2,53
MHBT	36,53±2,30*	38,72±3,15*	30,95±1,33
BM	44,25±2,48	37,92±3,69	39,12±2,46
	Strength impulse $H \cdot s \cdot 10^{-1}$		
SM	79,17±9,71	67,06±8,21	62,50±8,55
LDE	56,79±8,30	54,02±6,03	66,12±4,02
MHBT	50,23±3,42*	65,97±6,55*	41,15±2,85
BM	49,49±4,15	46,22±4,24	54,48±6,58

Table 3.
Velocity of isometric contraction of rat muscle fibers after 21-day exposure to accelerations

Muscle	Animal group		
	P	C	K
SM	34,61±2,16*	24,60±4,25	26,06±3,23
LDE	29,22±1,47	31,01±2,67	35,28±4,30
MHBT	14,03±0,40*	19,79±1,38*	11,88±0,85
BM	20,55±2,18	20,96±2,39	20,22±0,74

As we can see, the severity and direction of demonstrated changes in morphometric parameters of muscles and contractility of muscle fibers with exposure to accelerations are specifically related to functional specialization of the tested muscles, as well as difference in nature of changes in inertial forces when rotating on the centrifuge (groups P and C).

The first of these tendencies is manifested by the fact that, under the effect of accelerations, as was to be expected, there is selective increase in strength and efficiency of extensors performing an antigravity function (MHBT and SM), which is indicative of a substantially greater functional load on them under these conditions than on flexors (LDE and BM). In analogous (with respect to magnitude of accelerations) experiments, the same correlations were demonstrated between changes in strength of SM and LDE in preparations of isolated muscles (electrically stimulated contractions) and increase in strength properties of MHBT fiber preparations [8]. On the whole, these results are in agreement with data in the literature concerning increase in strength and resistance to fatigue of slow animal muscles with exposure to accelerations [17].

A comparison of the results obtained for animals in the two experimental groups shows that antigravity muscles seemingly identical in functional purpose--SM and MHBT--react differently to experimental conditions. As can be seen in Tables 1-3, changes in SM were demonstrated only in group P animals (+2 Gx), whereas the changes in contractility of MHBT were statistically significant and in the same direction in both experimental groups of rats. Evidently, this can be attributed to some morphofunctional and biomechanical distinctions of MHBT. The latter, being an active antigravity muscle [2], is referable to fast ones in velocity of contraction and, according to previously obtained data [7], it can be assumed that it contains mostly rapid and fatigue-resistant fibers--FR in the classification of Burke [12]. The higher sensitivity of MHBT to rotation could be due to the fact that it is in the foreleg, which is considerably less active in rats in antigravity function and, on the contrary, more adapted through evolution to highly differentiated movements. Such "polyfunctional" nature of MHBT implies that there is greater probability of its involvement in motor adaptation processes when environmental conditions change [7, 9], in particular when the magnitude and vector of gravity change.

The effect of accelerations on strength and efficiency of antigravity muscles, which we demonstrated in group P animals is the exact opposite of the effects of weightlessness [6, 7, 9]. However, even under these conditions, some distinctions were noted in MHBT reactions. They were manifested by the fact that the changes in strength and efficiency of MHBT fibers virtually failed to differ in direction and magnitude from those in SM, but the changes in velocity of contraction presented the same tendency as in preparations of BM, which is the rapid muscle of the foreleg [11]. At the same time, the results enable us to explain by AG aboard Cosmos-936 neutralized opposite changes in strength and efficiency of MHBT and BM fibers caused by weightlessness [8].

In this study, the findings as to a tendency toward increase in velocity of SM fibers in group P animals and MHBT fibers in both experimental groups were somewhat unexpected, since it had been previously shown [8] that there was slowing of isolated SM preparations exposed to accelerations (+2 Gx) for 22 days. One would think that this was related to a difference in method of testing the velocity of contractions of isolated muscle and muscle fiber preparations [8].

However, as shown in [15], exposure to accelerations of analogous duration and magnitude is associated with increase in relative amount of slow muscle fibers (classified by activity of ATPase of myosin and succinate dehydrogenase) to the detriment of fast ones, which is more distinctly noticeable in the P group of animals than in group C (+1.03 Gx). In this case, it remains for us to assume that the fact that in this study the experimental animals were kept in groups on the centrifuge (5 rats in each) in a container 60×40×30 cm in size, whereas in the above-mentioned experiments they were in individual cages [8] or in a container about half the size of ours [15]. The possibility cannot rule out that the fact that the animals were able to move about in a hypergravity field lends a dynamic nature to the load on antigravity muscles and, consequently, has a conditioning effect. Such effects (increased strength properties and velocity of muscular contraction) have been observed with some forms of physical training [13, 14] and artificial hypertrophy of antigravity muscles (due to amputation of synergists) in animals that retained the possibility for free movement [16]. Conversely, it is known that long-term static loads on antigravity muscles or their distension (for example, when kept in a small cage) leads to slowing of the contraction process [13], or else there is no noticeable change in strength of the muscles [5].

The results of investigations are discussed from the standpoint of the general conception of functional plasticity of muscles, and they confirm the opinion that there is highly differentiated manifestation of adaptation of skeletal muscles to change in gravity field [7, 11].

Our findings warrant the assumption that there is a more general pattern of adaptation of skeletal muscles to change in magnitude of the gravity field in both directions from 1 G. The nature and depth of adaptive changes in skeletal muscles under such conditions are determined not only by functional-metabolic and biomechanical distinctions of muscles but also, apparently, the different parameters of the exogenous "mechanical field" when its changes are in the same direction.

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HEMODYNAMIC PARAMETERS AS RELATED TO DIFFERENT TOLERANCE TO HEAD-PELVIS ACCELERATIONS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 19, No 5, Sep-Oct 85 (manuscript received 4 Jul 84) pp 56-60

[Article by N. I. Kokova]

[English abstract from source] Hemodynamic parameters in the subjects with various resistance to +Gz acceleration were investigated. Twelve test subjects were rotated 41 times in a 7.25 m-arm centrifuge. The acceleration value was increased slowly. During centrifugation ECG, systolic pressure in the ear lobe, stroke volume and cardiac output were measured. In the resistant subjects stroke volume remained stable and cardiac output was close to or higher than the initial level (due to tachycardia). In the non-resistant subjects both parameters decreased although their heart rate was significantly higher than in the resistant subjects. Various visual disorders developed when cardiac output decreased by 50-70% as compared to the initial level. It is concluded that in the nonresistant people the compensatory mechanisms responsible for the stability of cardiac output include primarily HR increase, whereas in the resistant people they involve a high level of venous return and stroke volume.

[Text] Information about changes in stroke volume (SV) and cardiac output (CO) is of special interest in assessing physical condition with exposure to longitudinal accelerations. There is sparse and contradictory information on this score in the literature. According to the results of investigations of most authors, SV and CO diminish under the effect of accelerations; however, there are also reports of relative stability of CO during long-term exposure to low-level accelerations [1, 2, 8, 10]. It can be assumed that CO changes depend on both the characteristics of accelerations (rate of build-up, plateau or peak profile, duration of exposure) and individual tolerance of man to accelerations. Such information is of practical interest for purposes of expert medical evaluation of pilots and in screening cosmonaut applicants.

Qualitative and quantitative evaluation of dynamics of CO changes could become an additional diagnostic sign for evaluation of man's resistance to accelerations.

Methods

Subjects were submitted to rotation on a centrifuge with a 7.25-m arm, generating gradually increasing accelerations in the head-pelvis direction to the maximum tolerated level. The gradient of build-up constituted 0.003 units/s. Rotation was stopped at the request of a subject, as well as according to conventional criteria of reaching maximum tolerance to accelerations. The tests were conducted without anti-G devices or any protective agents. During exposure to accelerations, the subjects contracted muscles of the prelum abdominale and lower extremities.

A total of 12 subjects participated in these studies, and each was submitted to accelerations 1 to 7 times. In all, we conducted 41 studies. We recorded the ECG in the three leads of Nehb [9], systolic arterial pressure (BP_S) in vessels of the ear lobe, SV and CO by the method of thoracic tetrapolar rheography with calculations made using the Kubicek formula as modified by Yu. T. Pushkar' et al. [4, 7]. Severity and nature of visual disturbances were assessed on the basis of subjective reports of our subjects.

All of the material was submitted to processing by the method of variational statistics according to Student.

Results and Discussion

We used the following ratings of the subjects' reactions to accelerations: high, moderate and low resistance.

A highly resistant reaction was recorded in 16 cases. In this group, tolerance to accelerations constituted a mean of 4.93 ± 0.197 units and ranged from 4.6 to 5.6 units. The group with moderate resistance consisted of 21 cases, in which the range of tolerance was from 3.8 to 4.6 units (average 4.34 ± 0.078 units). During rotation, subjects in this group presented isolated disturbances in heart rhythm, transient decrease in amplitude of pulse in ear lobe vessels and BP_S in vessels of the concha. In most cases, rotation was stopped at the subjects' request due to development of muscular fatigue.

Low-resistance reactions to accelerations were noted in four cases. In this group of individuals, mean level of accelerations constituted 3.7 ± 0.260 units; however, the actual limit of tolerance determined by physiological criteria was about 0.5 unit lower. This group included cases, in which an entire set of disturbances was recorded during rotation (for example, stable drop of BP_S of conchal vessels to 40 mm Hg or less, decrease in pulse amplitude of ear vessels to the isoline, along with numerous extrasystoles or prolonged migration of pacemaker from sinus node to the atrioventricular node). In one case, the subject developed a presyncopic state when brakes were applied to the centrifuge. Ear BP_S dropped to zero, heart rate (HR) reached 204/min and recovered only 10 min after the centrifuge was stopped. This subject presented vegetovascular dystonia (hypotensive type) with working BP level of 100/50-90/40 mm Hg.

It should be noted that the same subjects manifested different degrees of tolerance to accelerations in different tests. However, such fluctuations

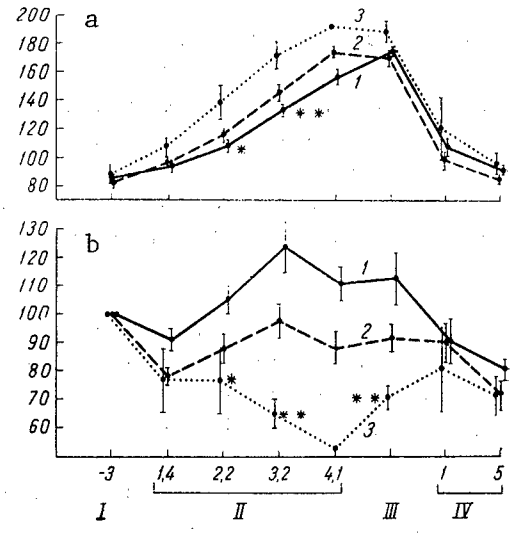

Figure 1.
Dynamics of HR (a, per min) and SV (b, %) with exposure to +Gz accelerations as related to different levels of tolerance
1, 2, 3) high, moderate and low resistance to accelerations, *P<0.02, **P<0.01, in comparing high and low resistance
Here and in Figure 2, x-axis:
I) 3 min before exposure
II) exposure to +Gz (units)
III) braking centrifuge
IV) 1st and 5th min of aftereffect period

in the same subjects amounted primarily to change of subjects with high resistance to accelerations to the moderately resistant group or vice versa.

Figure 1 illustrates the changes in CO and HR as related to different levels of resistance to accelerations. A comparison of physiological parameters had to be limited to 4.1 unit accelerations, since by far not all subjects could tolerate higher levels. The plot shows that up to 1.4 units subjects in all groups showed a decline to below base levels of CO. Evidently, this can be attributed to the fact that the main compensatory mechanisms had not yet been triggered. Upon further build-up of accelerations, CO dynamics differed in the three groups of subjects.

In individuals with high tolerance to accelerations, CO increased to levels exceeding the baseline. In those with moderate tolerance, the CO changes were analogous but somewhat lower in level and did not exceed base values. In the case of low resistance to accelerations, CO changed in a different way: With 1.4-2.2 unit-acceleration it held at 80% of the base level, then declined consistently to 50-65%. The decline of CO in cases of low resistance to accelerations occurred in spite of the fact that HR was reliably higher than in cases of high resistance. Consequently, the change in SV was the cause of this phenomenon.

Figure 2 illustrates the correlation between changes in SV and CO, as well as HR, in subjects differing in resistance to accelerations. With accelerations of 1.4 to 3.2 units, CO changed as a function of HR in highly resistant subjects. SV was relatively stable at this time and, consequently, CO was a function of HR. In spite of the fact that SV decreased by 50% after accelerations of 3.2 units, CO continued to remain on a level above the base value. In this group, the relatively minor increment of HR (by 86%) held CO on a high level. For this reason, there were rare instances of impaired vision among subjects with high resistance to accelerations. Narrowing of visual field, which could be interpreted as the early stage of a "gray" film, was recorded in only 1 cases (with accelerations of 4.8 units).

There was somewhat more marked decline of SV in the group with moderate tolerance to accelerations, CO depended less on HR and, starting at 3.2 units, CO diminished; the rise in HR could not compensate for the progressive decline of SV. The lower

CO did not always provide for satisfactory function of the visual analyzer; visual disorders were recorded in this group in 7 cases (33%).

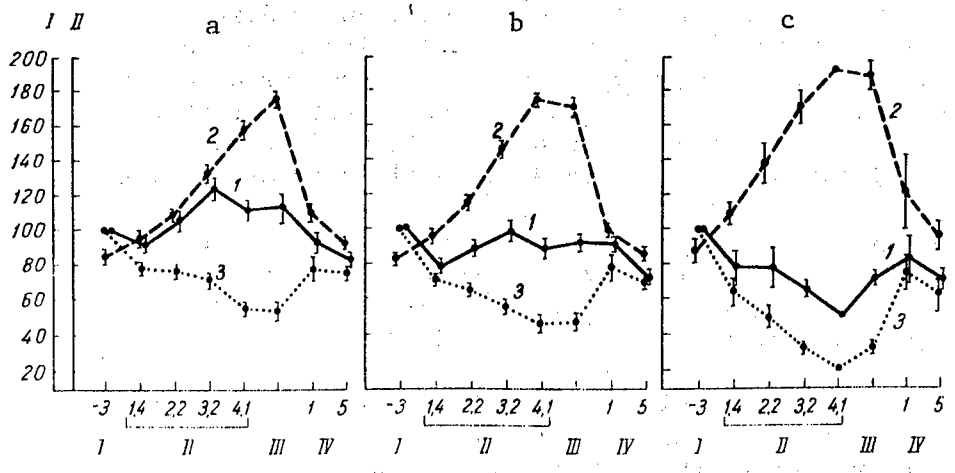

Figure 2. Dynamics of SV and CO (I, % of baseline) and HR (per min) during exposure to +Gz accelerations in cases of high (a), moderate (b) and low (c) resistance

1) CO 2) HR 3) SV

In the group with low resistance, no parallel was demonstrable between CO and HR. The decline of SV was so significant that a substantial HR increment provided a relatively stable CO (about 80% of base value) only with accelerations of up to 2.2 units; subsequent increase in HR (even by 121%) could not hold CO on a high level. In this group, visual disorders were recorded for all subjects; they were encountered in 50% of the cases during build-up of accelerations and in 75% when the centrifuge slowed down. A comparison of the incidence of visual disorders to CO changes shows that a decline of CO to 50-70% of the baseline was associated in most cases with onset of various forms of visual disorders, i.e., attainment of limit of tolerance (Figure 3). This is quite consistent with the data of D. Yu. Arkhangel'skiy and L. S. Plakhotnyuk [1], according to whom CO drops to 60% of the base value upon reaching maximum tolerance.

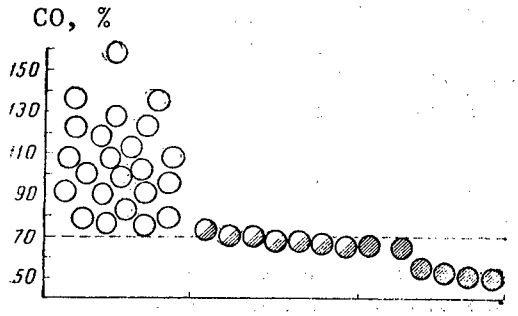

Figure 3.
Onset of visual disorders as a function of level of CO decline with accelerations of +4.1 Gz
White circles--clear vision; half-hatched--loss of peripheral vision; completely hatched--"gray" film

Consequently, compensatory reactions aimed at maintaining CO with exposure to head-pelvis accelerations differ in subjects with different resistance to accelerations.

Subjects with resistance to accelerations have good compensatory reactions to maintain SV on a high level. Probably, in this case their good physical conditioning made it possible to develop and hold at a constant level that was adequate to the accelerations muscular tension and this (along with reflex constriction of vessels) prevented significant redistribution of blood in a caudal direction and led to relative stability of venous return. During rotation, we observed moderate tachycardia because of which CO continuously increased. It is only after 3.2 unit acceleration that we observed some decline of CO with continued rise of HR. This discrepancy between CO and HR ("scissors") can be interpreted as an early sign of impaired compensation.

Compensatory reactions of subjects classified in the group with moderate resistance were essentially analogous to those observed with high resistance; however, CO was somewhat lower and "scissors" between CO and HR were demonstrable somewhat earlier, at 2.7-3.2 units.

In subjects with low resistance to accelerations, SV decreased the most. Compensatory reactions aimed at maintaining CO amounted essentially to increased HR. Probably, due to the drastic reduction of cardiac output in this group of subjects, there was the most significant reflex increase in HR. Nevertheless, CO dropped and was below the level at which satisfactory human work capacity and clear vision are still possible. Evidently, this happened because, in these cases, redistribution of blood in a caudal direction and, consequently, reduction of circulating blood volume were quite significant. In our opinion, this could be caused by both insufficient physical endurance and hypotensive type of vegetovascular dystonia. Insufficient conditioning of muscles, in particular those of the legs and prelum abdominale, did not enable them to maintain a high level of muscular tension for a prolonged time. As a result, there was deposition of excessive blood in vessels of the lower extremities, and it could constitute 10 to 30% of total blood volume, according to some reports [5]. As for an explanation for the low resistance to accelerations in the subject with vegetovascular dystonia of the hypotensive type, there are indications in the literature of a moderate correlation between tolerance to +Gz accelerations and baseline BP_S [6]. V. L. Karpman et al. [3] relate this to the fact that the decline of venous return in the case of exposure to gravity factors of hypotensive subjects is more marked and associated with greater increase of HR. A lag of CO from rise of HR (or start of decompensation) in subjects classified as having low resistance was observed from the first minutes of exposure to accelerations (about 1 unit). In this group of subjects, CO was almost proportionate to SV, which means it was also proportionate to venous return.

Thus, in cases of high tolerance to slowly increasing accelerations, CO holds on a stable level or even increases in comparison to the baseline. A decline of CO with exposure to accelerations can be viewed as a prognostically unfavorable reaction inherent in individuals with low resistance. According to our data, a 30-50% decline of CO as compared to the base value is associated with various forms of visual disturbances.

Use of anti-G suits, which prevent redistribution of blood in a caudal direction, as well as other means of increasing venous return and circulating blood volume, should be recommended for individuals with low resistance to head-pelvis accelerations.

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UDC: 612.744.2:612.744.14.014].477-063

CHANGES IN PHYSICOCHEMICAL PROPERTIES OF CONTRACTILE AND REGULATORY PROTEINS IN DIFFERENT TYPES OF MUSCLES DURING AND AFTER EXPOSURE TO ACCELERATIONS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 19, No 5, Sep-Oct 85 (manuscript received 18 Apr 84) pp 60-64

[Article by B. A. Tikunov, M. A. Kayfadzhyan and S. S. Oganesyan]

[English abstract from source] After 15-day exposure to +5 Gx the rate of superprecipitation, Mg^{2+}-ATPase activity and actomyosin ATPase of slow muscles (m. soleus and medial head of m. triceps brachii) of white rats increased greatly. In actomyosin of fast muscles (m. brachialis and m. extensor digitorum longus) the exposure induced weaker and opposite changes in the superprecipitation rate and Mg^{2+}-ATPase activity. The changes in actomyosin of the fast muscles were associated with shifts only in regulatory components while those of the slow muscle were produced by shifts in contractile proteins as well. This provided for a better recovery of the initial value of the superprecipitation rate and Mg^{2+}-ATPase activity of actomyosin of the fast muscles a month after exposure.

[Text] Increased physical load on muscles is one of the factors that can alter differential activity of genes, impairing the spectrum of synthesized isoforms of myofibrillar proteins [5, 8]. It has been shown that, under such conditions, there is change in properties of both regulatory and contractile proteins contained in the actomyosin complex [2, 4]. However, the relative role of disturbances in these two different protein components in providing for specific adaptive changes in muscular actomyosin of different phenotypes is still unclear. This question acquires even more importance in view of reports of dissimilar changes in biomechanical and histochemical characteristics of fast and slow skeletal muscles of vertebrates that develop under the influence of a functional overload [9-12].

On the other hand, the recovery rate for functional parameters of actomyosin after functional overload is removed from animals should depend, to some extent, on the degree of "vulnerability" of regulatory and contractile proteins of muscles characterized by dissimilar rates of renewal [14]. On the basis of these considerations, we tried to demonstrate a link between the specifics of adaptive and recovery changes in physicochemical properties of actomyosin of fast and slow skeletal muscles.

Methods

Albino Wistar rats (120 males) were divided into 3 groups (vivarium control--1st; experimental--2d submitted to the functional overload factor and 30-day recovery group--3d). A functional overload of skeletal muscles was produced by rotating the animals on a centrifuge at accelerations of +5 Gx for 25 min per day for 15 days.

We took muscles of the anterior and posterior extremities for examination from animals decapitated under ether anesthesia: medial head of brachial triceps (MHBT) and brachial muscle (BM); long digital extensor (LDE) and soleus (SM). Unadulterated actomyosin was isolated by the method in [16] with additional purification by means of ultracentrifugation. Desensitized actomyosin (i.e., without tropomyosin-troponin--TM-TN--complex) was recovered from the suspension of unadulterated actomyosin by means of manifold alkaline elution [17]. Purity of protein preparations was checked by electrophoresis on polyacrylamide gel [18], while concentration of proteins was assayed by the Lowry method and spectrophotometry, using lyophilized actomyosin as the standard.

The kinetic curves of superprecipitation (SPP) and Mg^{2+}-ATPase activity were recorded on a unit assembled according to [3]. SPP rate was calculated from the change in optical density (OD) of the protein suspension on the rectilinear segment of SPP curves and Mg^{2+}-ATPase, from the quantity of inorganic phosphate (P_i) dissociated in 5 s (for simplification of calculations and recording results). The obtained experimental data were submitted to statistical processing with use of Student's criterion.

Results and Discussion

Native actomyosin of SM and MHBT in the 1st group of animals was characterized by lower rate of SPP and Mg^{2+}-ATPase activity than in BM and LDE preparatoins (Table 1). There was a good correlation between rate of SPP and Mg^{2+}-ATPase activity of native actomyosin from different types of muscles, which conforms to data published previously [13, 15]. On the other hand, more intensive rise in rate of SPP, as compared to Mg^{2+}-ATPase activity, upon moving from unadulterated actomyosin of SM and MHBT to protein preparations of BM and LDE resulted in higher efficiency of actomyosin ATPase of the latter.

Removal of regulatory proteins from unadulterated actomyosin, i.e., desensitization of actomyosin, led to increase in rate of SPP and Mg^{2+}-ATPase, which can be attributed to removal of the inhibitory effect of the TM-TN complex [1]. We should call attention to the differences in magnitude of the inhibitory effect of TM-TN on rate of SPP and Mg^{2+}-ATPase activity of actomyosin in slow and fast skeletal muscles. Thus, while the TM-TN complex inhibited Mg^{2+}-ATPase 1.29 and 1.43 times more than SPP rate in native actomyosin of SM and MHBT, its effect on Mg^{2+}-ATPase activity of native actomyosin in BM and LDE was 2.35 times stronger than on SPP rate. Expressly this caused lower efficiency of ATPase in desensitized actomyosin of BM and LDE, as compared to the corresponding preparations of native actomyosin. This was not observed in the case of SM and MHBT, where removal of TM-TN complex from native actomyosin did not have an appreciable effect on efficiency of actomyosin ATPase.

Table 1. Changes in physicochemical properties of native actomyosin of rat skeletal muscles under effect of periodic accelerations and after readaptation for 1 month (M±m)

Muscle	Animal group	SPP rate (ΔOD/Δt)	Mg^{2+}-ATPase activity ($\Delta P_i/\Delta t$)	Efficiency ($\Delta OD/\Delta P_i$)	n
SM	1	0,27±0,01	0,35±0,02	0,76±0,05	5
	2	0,70±0,03	0,75±0,03	0,96±0,06	8
	3	0,39±0,01	0,44±0,01	0,88±0,04*	5
MHBT	1	0,33±0,03	0,40±0,06	0,82±0,07	6
	2	0,51±0,01	0,49±0,02*	1,05±0,06*	8
	3	0,42±0,01	0,47±0,01*	0,88±0,03*	7
BM	1	1,20±0,07	1,00±0,03	1,20±0,09	6
	2	1,23±0,01**	0,83±0,02	1,53±0,04	7
	3	1,08±0,01	1,04±0,08**	1,03±0,05	7
LDE	1	1,47±0,06	1,20±0,02	1,21±0,10	5
	2	1,00±0,01	1,03±0,07	0,97±0,07	6
	3	1,42±0,02**	1,10±0,08*	1,29±0,11**	5

Note: Here and in Table 2, *P≤0.1, **P>0.5 in relation to control. In other cases P<0.05; n--number of experiments. Incubation medium: [AM] = 0.5 mg/mℓ, 20 mM tris-HCl, 0.15 M KCl, β-mercaptoethanol pH 7.35, 0.5 mM Mg^{2+}-ATP, t = 25°C. For SPP λ_{reg} = 660 nm.

Table 2. Changes in physicochemical properties of desensitized actomyosin of rat skeletal muscles under effect of periodic accelerations and after readaptation for 1 month (M±m)

Muscle	Animal group	SPP rate (ΔOD/Δt)	Mg^{2+}-ATPase activity ($\Delta P_i/\Delta t$)	Efficiency ($\Delta OD/\Delta P_i$)	n
SM	1	0,36±0,01	0,50±0,02	0,72±0,04	5
	2	0,66±0,01	0,81±0,06	0,82±0,02	8
	3	0,51±0,05	0,65±0,02	0,79±0,10**	8
MHBT	1	0,48±0,02	0,66±0,01	0,72±0,04	7
	2	0,61±0,01	0,70±0,02*	0,87±0,03	6
	3	0,52±0,02	0,71±0,04*	0,73±0,06**	7
BM	1	1,53±0,06	1,63±0,02	0,93±0,04	7
	2	1,47±0,03**	1,56±0,05	0,91±0,04**	7
	3	1,44±0,04*	1,66±0,36**	0,87±0,10**	7
LDE	1	1,62±0,04	1,49±0,03	1,09±0,04	6
	2	1,53±0,02	1,42±0,02*	1,07±0,02**	8
	3	1,57±0,03**	1,54±0,07**	1,02±0,06**	8

Consequently, the inhibitory effect of the TM-TN complex is apparently implemented by different mechanisms and modulates dissimilarly the functionally important properties of unadulterated actomyosin of skeletal muscles that contract rapidly and slowly. It is also important to note that the differences in rate of SPP, Mg^{2+}-ATPase activity and efficiency of ATPase of native actomyosin of the tested muscles persisted between the corresponding preparations of desensitized actomyosin in about the same batches. This indicates that the typical distinctions of physicochemical properties of native actomyosin are attributable primarily to contractile proteins proper--actin and myosin.

Periodic accelerations elicited dissimilar changes in properties of native actomyosin of fast and slow muscles (see Table 1). The rate of SPP and Mg^{2+}-ATPase activity of native actomyosin of SM and MHBT increased markedly in the 2d group of animals, whereas in native actomyosin of BM and LDE these parameters decreased (with the exception of SPP rate of BM native actomyosin). These findings agree well with data on increase in rate of development of contraction by glycerin-treated SM and MHBT fibers under the effect of gravity overloads [11].

Changes induced by a working overload were considerably less marked in preparations of desensitized actomyosin of BM and LDE than in corresponding preparations of native actomyosin (Table 2). Consequently, the main disturbances occur in these muscles apparently in regulatory proteins, i.e., in the TM-TN complex. The inhibitory effect of TM-TN on Mg^{2+}-ATPase activity of unadulterated actomyosin of BM and LDE increased 1.38 and 1.63-fold in the 2d group of animals, while its capacity to lower the rate of SPP of LDE native actomyosin increased about 5.5-fold, as compared to control preparations. This could be related to appearance of a second inhibitory subunit of TN-1 in the presence of a functional overload [2].

In contrast to BM and LDE, there was attenuation of the inhibitory effect of the TM-TN complex on SPP rate and Mg^{2+}-ATPase activity of native actomyosin in SM and MHBT preparations; however, the basic differences between experimental and control values for the tested parameters persisted also in the corresponding preparations of desensitized actomyosin. This indicates that, in contrast to fast muscles, periodic accelerations induce changes not only in regulatory, but contractile proteins of slow muscles, and it confirms the data of A. N. Potapov to the effect that slow skeletal muscles are more sensitive to changes in physical loads [7].

The efficiency of actomyosin ATPase increases drastically under the effect of periodic accelerations in native and desensitized actomyosin of SM and MHBT, whereas its changes are dissimilar in native actomyosin of BM and LDE, and they are statistically unreliable in the corresponding preparations of desensitized actomyosin. Perhaps, the changes in efficiency of actomyosin ATPase also play an important part in the compensatory reaction of slow antigravity skeletal muscles to an increase in physical load.

After readaptation for 1 month to normal physical loads, there was virtually complete restoration of baseline values for the tested parameters in BM and LDE actomyosin, which is very consistent with reports of high degree of reversibility of changes in biomechanical characteristics of these muscles when animals are removed from extreme conditions [6].

The situation was somewhat different for muscles that contract slowly. The inhibitory effect of the TM-TN complex, which had been markedly attenuated by the working overload, as well as efficiency of actomyosin ATPase after 1-month readaptation, were restored, but the SPP rate and Mg^{2+}-ATPase activity of native and desensitized actomyosin of SM and MHBT remained reliably higher than in control preparations of the protein. This suggests that changes related to regulatory components of the native actomyosin complex recover faster and more completely, i.e., they are more reversible that those based on

changes in contractile proteins themselves. Faster replenishment of regulatory proteins could be one of the causes of this phenomenon [14].

Thus, the contractile protein system of rat muscles that contract slowly is more sensitive to periodic accelerations than that of fast skeletal muscles. The changes in rate of complex formation (SPP rate) and Mg^{2+}-ATPase activity of actomyosin of slow muscles are the opposite of those observed in protein preparations from fast muscles and, unlike the latter, are attributable to changes not only in regulatory but contractile proteins. Apparently, expressly such different etiogenesis of changes causes fuller restoration of base values for the tested parameters of physicochemical properties of fast muscle protein preparations.

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CUMULATIVE EFFECT OF CORIOLIS ACCELERATIONS ON CORONARY HEMODYNAMICS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 19, No 5, Sep-Oct 85 (manuscript received 7 Sep 84) pp 64-68

[Article by E. V. Lapayev and V. S. Bednenko]

[English abstract from source] Time-course variations in coronary circulation and cardiac output were measured in 29 healthy test subjects who performed tests with a continuous cumulation of Coriolis accelerations and in 12 healthy test subjects who were exposed to Coriolis accelerations combined with acute hypoxia. Adaptive changes in coronary circulation were seen. It is recommended to monitor coronary circulation during vestibulometric tests as part of medical expertise of the flying personnel.

[Text] Development of motion sickness (MS) during flight in air or space (and, in particularly, under the cumulative effect of Coriolis accelerations) can, in a number of instances, be the cause of diminished operator work capacity, which leads to worsening of performance of flight assignments [11]. A certain role in the MS problem is attributed to instrumentation methods and means of medical monitoring of operators' condition in flight and during ground-based training. These methods permit objective evaluation of the nature and extent of adaptive change in physiological functions [7]. The work of a number of authors is devoted to investigation of hemodynamic reactions under such conditions [5, 7, 13]. At the same time, questions of intensity of function of mechanisms controlling coronary circulation have not yet been explored. Our objective here was to assess the functional distinctions of these mechanisms during performance of typical vestibulometric tests.

Methods

We conducted 3 series of studies involving healthy subjects 28-30 years of age.

In series I, we examined 29 people during performance of the vestibulometric test by the method of continuous build-up of Coriolis accelerations (CBCA) [8]. They were rotated at the rate of 180°/s using a series-produced vestibulometric chair in seated position, with alternate inclination of the head to each side at an angle of at least 30°. The occurring vestibulovegetative reactions (VVR) were classified according to K. L. Khilov [16]. The

test was stopped upon development of grade III VVR (VVR III). In the absence of VVR III, maximum duration of the test was 15 min.

We recorded the electrocardiogram (ECG) in the D-S lead and ultrasonic doppler cardiogram (USDC) from a region that enabled us to probe the posterior wall of the left ventricle of the heart (6th intercostal space on the left, near the sternum) [4]. From the ECG, we determined heart rate (HR). Using the integral values of signal level in systole on the USDC [3], we assessed the dynamics of effective coronary blood flow (ECBF), which reflects the amount of blood flowing through coronary vessels that gives off oxygen into the myocardial capillaries. Dynamics of stroke output were determined from the integral USDC frequency in the sphygmic interval with conversion to increment of left ventricular volume [2].

Relative changes in stroke ECBF ($\overline{SECBF}$) and stroke volume ($\overline{SV}$) were determined using the formulas: $\overline{SECBF} = A/A_0$ and $\overline{SV} = F/F_0$, where A and F are integral values for signal amplitude in systole and frequency in sphygmic interval, respectively, under the effect of CBCA, A_0 and F_0 are the same in the baseline state.

Relative changes in minute effective coronary blood flow ($\overline{MECBF}$) and minute volume ($\overline{MV}$) were calculated using the formulas: $\overline{MECBF} = SECBF \times \overline{HR}$ and $\overline{MV} = \overline{SV} \cdot \overline{HR}$, where $\overline{HR} = HR/HR_0$ is the ratio of HR during exposure to CBCA to base HR.

Integral values of the parameters were determined using analogue converters [14].

In the second series of studies, we examined 12 subjects exposed to the combination of CBCA and hypoxic hypoxia, with recording of ECG and USDC, in order to detect the "latent" form of motion sickness [17]. Before rotating the subject, he breathed a gas mixture containing 10.5% oxygen and 89.5% nitrogen, which corresponded to ascent to 5000 m, for 30 min. During rotation, the respiratory system was switched to self-contained delivery of gas mixture from tanks situated right on the vestibulometric chair.

In the third series of studies, which was conducted to asses the contribution of CBCA and hypoxic hypoxia to development of hemodynamic reactions, we studied 15 subjects using the above-mentioned gas mixture for breathing, without the CBCA test.

Results and Discussion

VVR III was recorded in 27 out of 29 subjects under the effect of CBCA; rotation time constituted 1 to 15 min (7±2 min).

During the above test, SECBF rose distinctly (see Table). Its increment in relation to baseline values decreased somewhat with increase in motion sickness and constituted a mean of 2.3-fold with VVR I to 2.14 with VVR III. By the 5th min of the recovery period it remained 1.56-fold higher.

There was 2.88-, 2.28- and 2.17-fold increase in $\overline{MECBF}$ with VVR I, II and III, respectively, i.e., there was also a tendency toward decrease with increase in degree of motion sickness. $\overline{MECBF}$ was formed considerably more

Changes in hemodynamic parameters under effect of CBCA and acute hypoxia (M±m)

Parameter		CBCA						CBCA and acute hypoxia						Acute hypoxia	
		VVR			recovery period, min			VVR			recovery period, min			respiration time, min	
		I	II	III	1	3	5	I	II	III	1	3	5	10	20	30
$\overline{HR}$	P	1,11±0,05 <0,05	1,02±0,03 >0,05	0,99±0,03 >0,05	0,93±0,02 <0,01	0,92±0,03 <0,02	0,88±0,03 <0,001	1,11±0,03 <0,02	1,08±0,04 >0,05	1,05±0,05 >0,05	1,00±0,04 >0,05	0,90±0,04 <0,05	0,87±0,07 >0,05	1,03±0,03 >0,05	1,01±0,03 >0,05	0,99±0,03 >0,05
SECBF	P	2,30±0,58 <0,05	2,20±0,36 <0,01	2,14±0,27 <0,001	1,66±0,21 <0,01	1,56±0,20 <0,01	1,50±0,22 <0,05	2,05±0,23 <0,01	2,13±0,35 <0,01	2,75±0,52 <0,01	2,84±0,58 <0,01	2,02±0,37 <0,02	2,30±0,78 >0,05	1,92±0,22 <0,01	1,81±0,27 <0,01	2,11±0,30 <0,01
$\overline{MECBF}$	P	2,88±0,64 <0,05	2,26±0,39 <0,01	2,17±0,31 <0,001	1,49±0,20 <0,05	1,46±0,20 <0,05	1,33±0,20 >0,05	2,31±0,30 <0,01	2,65±0,42 <0,01	3,10±0,69 <0,02	2,89±0,64 <0,02	1,87±0,39 <0,05	1,94±0,63 >0,05	1,97±0,24 <0,01	1,85±0,27 <0,01	2,02±0,25 <0,01
MECBF*	P	3,81±0,68 <0,02	3,31±0,51 <0,01	1,81±0,20 <0,01												
$\overline{SV}$	P	0,97±0,05 >0,05	0,99±0,07 >0,05	0,90±0,05 >0,05	1,00±0,10 >0,05	1,00±0,08 >0,05	0,99±0,07 >0,05	1,05±0,08 >0,05	1,14±0,09 >0,05	1,08±0,10 >0,05	1,10±0,18 >0,05	1,07±0,15 >0,05	1,09±0,14 >0,05	1,22±0,11 >0,05	1,25±0,09 <0,02	1,23±0,08 <0,02
$\overline{MV}$	P	1,10±0,08 >0,05	1,02±0,07 >0,05	0,85±0,06 >0,05	0,92±0,11 >0,05	0,93±0,07 >0,05	0,91±0,08 >0,05	1,18±0,12 >0,05	1,25±0,14 >0,05	1,17±1,15 >0,05	1,14±0,22 >0,05	0,97±0,12 >0,05	1,00±0,17 >0,05	1,26±0,13 >0,05	1,24±0,08 <0,02	1,22±0,08 <0,02

*Data for group of 9 subjects characterized by marked decline of MECBF with VVR III.

at the expense of stroke coronary blood flow than HR. With VVR III, in 9 out of 29 subjects $\overline{MECBF}$ underwent a marked decline (to 1/3d) as compared to the level reached with VVR I, remaining, however, above base values. The other hemodynamic parameters ($\overline{HR}$, $\overline{SECBF}$, $\overline{SV}$, $\overline{MV}$) of these 9 subjects showed no differences from the mean group values. In the recovery period, $\overline{MECBF}$ dropped to a level of 1.33.

The changes in SV and MV were considerably less marked. The greatest decline of these parameters, which constituted 10 and 11%, respectively, were noted with VVR III.

Such dynamics of coronary circulation parameters indicate that, in the general pattern of circulatory changes under the effect of CBCA, there are marked adaptive reactions of coronary blood flow which reflect the increased oxygen requirement of the myocardium. The findings are consistent with the previously described [1, 10] distinction of mechanisms of regulating coronary blood flow, which consists of their ability to augment blood volume in the coronary system in the presence of low (or unchanged) $\overline{SV}$ and $\overline{MV}$. In our opinion, one should mention first of all marked dilatation of coronary vessels, which is typical of various stress states, among the most probable mechanisms of controlling ECBF during exposure to CBCA [14].

When evaluating the recorded ECBF values, one should bear in mind that the 30% decline of coronary blood flow as compared to the level corresponding to metabolic requirements of the myocardium can already lead to early electrocardiographic signs of coronary insufficiency in the form of changes in ST segment and T wave ("threshold" changes) [1]. Since development of more marked motion sickness than VVR I is usually associated with intensification of hemodynamic reactions and load on the heart [5, 7, 12], it is apparent that metabolic requirements of the myocardium

are not lower than with VVR I. Considering the foregoing, the mean decline of MECBF, which constituted about 25% by the time of development of VVR III as compared to the level reached with VVR I, should be assessed as a change that is close to but not reaching the threshold. At the same time, the decline of ECBF was distinct in nine subjects, and blood flow was below the threshold level. This is indicative of some inadequacy of blood supply to the myocardium in relation to its metabolic requirements. Since increase in coronary blood flow is the main route of providing for the increased myocardial oxygen requirements [1, 15], it can be assumed that vasodilatation of coronary vessels as a mechanism of controlling ECBF with VVR III is no longer effective in these subjects.

It should be noted that, in the studies of V. I. Kopanev and Ye. M. Yuganov [6], as well as V. M. Tardov et al. [12], a decline of amplitude of T wave was noted as one of the signs characterizing ECG changes in the presence of motion sickness. And, although such ECG changes are inherent in a number of states (including stress situations), we cannot rule out the probable role of restricted coronary circulation in their genesis, since the presence of "low" T waves is also noted with coronary insufficiency [9].

The direction of changes in $\overline{SV}$ and $\overline{MV}$ coincided with reports in the literature [5, 7]. However, the decline of these parameters was less marked. This is apparently due to the fact that, in our studies, we reached a lesser degree of VVR than in the cited works. For example, we did not have a single case of vomiting or precollaptoid state.

In the second series of studies, with the combination of CBCA and acute hypoxic hypoxia, mean tolerance to exposure until there was development of VVR III decreased in duration and lasted 5±1.5 min. Poor tolerance to the combination of the two factors was demonstrated in 3 out of 15 subjects who had been classified, on the basis of the first series of studies, as having average vestibular resistance.

During development of VVR, $\overline{SECBF}$ rose from 2.05-fold as the average with VVR I to 2.75 with VVR III (see Table). After stopping the test, it continued to rise in the 1st min of the recovery period to 2.84-fold and by the 5th min of the aftereffect period it was higher than with VVR I. The nature of changes in $\overline{MECBF}$ was analogous: 2.31-fold increase with VVR I and 3.1-fold with VVR III. By the 5th min of the recovery period it was 1.94 times higher than in the base state. The changes in $\overline{SV}$ and $\overline{MV}$ were insignificant.

In the third series, where the subjects were in satisfactory condition throughout the test, $\overline{SECBF}$ increased by 1.84-2.11 times when breathing the gas mixture (see Table). In the presence of insignificant rise of $\overline{HR}$, the increase in $\overline{MECBF}$ was about the same. $\overline{SV}$ and $\overline{MV}$ rose somewhat, but unreliably. The noted dynamics of $\overline{HR}$ and cardiac output, as well as direction of changes in coronary circulation, virtually coincided with results obtained elsewhere under similar conditions [11].

Consequently, with intensification of motion sickness (first series of studies) we first observe a decline of coronary blood flow, and during intensification of hypoxia (third series), a rise. Hence, the hypoxic factor (which is a

powerful coronary-dilating stimulus [11]) plays the leading role in the genesis of gradual build-up of ECBF parameters under the combined effect of CBCA and hypoxia. Moreover, the marked increase in coronary blood flow in the recovery period is proof of development of reactive myocardial hyperemia (as a result of accumulation of metabolic products in heart tissues [15]) inherent in hypoxia during exposure to the combined factors. Evidently, development of reactive hyperemia under these conditions prevents the tendency toward reduction of blood flow as a component of a purely vestibular reaction, i.e., it is physiologically a more beneficial reaction.

Thus, during development of motion sickness in the course of the CBCA test, adaptive reactions of coronary circulation are formed already with VVR I. VVR III is characterized by general decline of current values for MECBF coming close to the threshold level in the presence of some decrease in ejection of blood. In about one-third of the subjects, ECBF drops below the threshold level, which reflects the inconsistency between blood supply to the myocardium and its metabolic requirements. As VVR progresses under the combined effect of CBCA and acute hypoxic hypoxia, one observes progressive increase in coronary circulation, which resembles somewhat changes on the order of functional hypperreaction of coronary circulation. Since vestibulometric tests are commonly used in expert medical certification of flight personnel [11] and coronary circulatory reactions may be substantial under these conditions, it should be deemed expedient to monitor ECBF on the basis of SECBF in assessing tolerance to vestibular factors.

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NYSTAGMUS AS RELATED TO UTRICULAR FUNCTION

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[Article by Yu. K. Stolbkov]

[English abstract from source] The horizontal neck nystagmus arising in response to angular acceleration was recorded electromyographically in pigeons (Columba livia). After bilateral section of the utricular nerves (Ramuli utriculi) the nystagmic reactions to the right and to the left remained symmetrical although they were delayed when compared to the reactions of intact animals. Unilateral section of the utricular nerves caused asymmetric reactions from the semicircular canals: the nystagmus toward the dissected nerve was delayed to a greater extent than that toward the intact nerve.

[Text] Nystagmus, which occurs upon stimulation of the semicircular canals (SC), is used extensively as a diagnostic sign in neurological and otorhinolaryngological clinical practice, in professional screening, training, etc. [2]. This reaction is caused primarily by stimulation of SC, and it is also subject to the influence of otolithic organs (OO). This is indicated by a number of factors, but there is no agreement about the mechanisms of such influence [1, 5, 6, 8, 12, 13].

The question of dependence of nystagmus on condition of OO, when their function is partially or entirely excluded, is of particular interest. An answer to this question would enable us to determine the nature of OO effect on nystagmus and consider the contribution of otolith function to formation of reaction from the SC.

Our objective here was to make a quantitative evaluation of the effect of unilateral and bilateral exclusion of utriculi on nystagmus elicited by angular accelerations.

Methods

We rotated pigeons (Columba livia), which were firmly immobilized in a special stand, in the dark horizontally following a trapezoid program: positive angular acceleration of $10°/s^2$--rotation at constant angular velocity of

166.6°s for 2 min--negative angular acceleration of $10°/s^2$. The axis of rotation passed between the labyrinths, while horizontal SC were in the plane of rotation. We alternated the direction of rotation; there were 2-min intervals between the "trapezoids."

Cervical nystagmus was recorded on an N-177 loop oscillograph by deriving biopotentials from the left and right m. rectus capitis posticus major using silver needle electrodes (0.3 mm in diameter). Potentials were amplified with a Diza 13-A-69 electromyograph.

We used unilateral and bilateral transection of utricular nerves (ramuli utriculi) to eliminate utricular function. The technique for cutting individual branches of the vestibular nerve was described in detail previously [9].

We conducted 12 series of experiments on 12 pigeons. Each series consisted of three experiments: recording of nystagmus in intact pigeons, as well as in birds following unilateral and bilateral transection of the utricular nerve. Each experiment was performed on the day after either surgery; each experiment consisted of 12 "trapezoids" (6 to the right and 6 to the left).

Results and Discussion

In each pigeon, the nystagmic reactions to the right (regardless of whether they were induced by positive or negative accelerations) were viewed as one group,* and those to the left as another. For each group, we calculated mean latency periods (LP)**, duration of reaction (DR) and number of beats (NB) per reaction.

The Table lists mean values and errors for different characteristics of cervical nystagmus in intact pigeons and those with transected utricular nerves.

As can be seen in this table, unilateral transection of utricular nerves elicits drastic inhibition of reactions in the direction of the operated labyrinth: as a result of the operation LP increased by several times, while DR and NB decreased. These changes were reliable ($P = 0.05$). In some pigeons (Nos 8-12), there was complete inhibition of nystagmus in the direction of the operated labyrinth after unilateral transection of the utricular nerve. Changes in nystagmus toward the intact labyrinth were less marked: there was virtually no change in LP, some decline (but unreliable) in DR and reliable (with the exception of pigeon No 1) decrease in NB.

After bilateral transection of utricular nerves, reactions to the right and left were equally inhibited. There was total inhibition of nystagmus in pigeons Nos 6-12.

It should be noted that transection of one or both utrical nerves was not associated in any of the pigeons with appearance of spontaneous nystagmus, which is indicative of intact condition of nerves innervating the SC.

*A comparison of rotatory and postrotatory reactions in the same direction revealed that they do no differ either quantitatively or qualitatively.

**LP--time from start of angular acceleration to start of slow component of first nystagmic jerk.

Mean values of some characteristics of cervical nystagmus in pigeons before and after transection of utricular nerves (M±m)

Pigeon No	Intact pigeon						Pigeon with unilateral transect. of utricular nerve						Pigeon with bilateral trans. of utricular nerves					
	stimulated labyrinth																	
	right			left			intact			operated			right			left		
	LP, s	DR, s	NB	LP, s	DR, s	NB	LP, s	DR, s	NB	LP,s	DR,s	NB	LP,s	DR,s	NB	LP,s	DR,s	NB
1	0,27 ±0,03	23,50 ±0,28	15,00 ±1,40	0,35 ±0,03	23,50 ±0,27	16,25 ±1,12	0,20 ±0,02	20,50 ±0,27	13,50 ±0,42	1,25 ±0,14	16,25 ±0,42	10,00 ±0,56	1,25 ±0,14	12,25 ±0,96	4,25 ±0,56	1,50 ±0,02	10,17 ±0,98	3,67 ±0,28
2	0,35 ±0,03	15,13 ±0,42	25,25 ±1,12	0,32 ±0,03	14,75 ±0,28	25,50 ±0,84	0,33 ±0,06	13,25 ±0,14	14,00 ±0,56	1,20 ±0,11	8,50 ±0,28	3,50 ±0,28	1,00 ±0,11	10,00 ±0,14	3,50 ±0,28	0,70 ±0,28	8,25 ±0,98	3,50 ±0,28
3	0,33 ±0,02	19,01 ±0,54	43,43 ±1,05	0,34 ±0,01	20,48 ±0,35	40,29 ±1,51	0,28 ±0,02	18,58 ±0,35	28,50 ±0,34	0,97 ±0,10	12,33 ±0,27	17,33 ±1,02	0,98 ±0,28	9,73 ±0,62	11,67 ±1,40	0,93 ±0,03	14,43 ±1,31	12,00 ±0,84
4	0,23 ±0,03	16,50 ±1,26	36,75 ±1,41	0,25 ±0,03	16,85 ±1,04	37,25 ±1,40	0,25 ±0,06	10,75 ±0,25	15,25 ±0,28	0,65 ±0,06	10,50 ±0,28	5,75 ±0,56	0.81 ±0,06	8,64 ±0,27	5,50 ±0,40	1,03 ±0,06	8,21 ±0,22	4,10 ±0,22
5	0,25 ±0,03	12,80 ±0,11	17,50 ±0,29	0,25 ±0,03	13,00 ±0,31	17,50 ±0,042	0,28 ±0,04	10,17 ±0,52	11,50 ±0,31	0,90 ±0,04	8,25 ±0,41	6,34 ±0,33	0,75 ±0,08	8,63 ±0,28	4,25 ±0,29	0,80 ±0,07	8,25 ±0,30	5,00 ±0,77
6	0,34 ±0,02	18,00 ±0,43	24,20 ±1,08	0,33 ±0,02	18,80 ±0,32	27,80 ±0,76	0,32 ±0,04	16,58 ±0,27	14,33 ±1,41	1,38 ±0,04	9,92 ±0,35	5,83 ±0,53	—	—	—	—	—	—
7	0,25 ±0,03	25,38 ±0,32	26,00 ±1,12	0,28 ±0,03	24,62 ±0,14	26,75 ±1,40	0,26 ±0,02	23,60 ±0,63	16,40 ±1,68	1,05 ±0,06	18,00 ±0,84	4,00 ±0,56	—	—	—	—	—	—
8	0,32 ±0,02	15,33 ±0,18	30,00 ±1,06	0,33 ±0,02	16,25 ±0,44	31,33 ±1,23	0,32 ±0,02	14,13 ±0,62	17,66 ±0,89	—	—	—	—	—	—	—	—	—
9	0,22 ±0,02	17,83 ±0,79	49,81 ±0,96	0,23 ±0,04	16,42 ±0,71	48,95 ±0,87	0,25 ±0,03	11,50 ±0,26	30,50 ±0,31	—	—	—	—	—	—	—	—	—
10	0,30 ±0,06	16,88 ±0,42	44,25 ±1,16	0,31 ±0,03	18,37 ±0,56	44,50 ±1,28	0,27 ±0,04	16,17 ±0,71	25,83 ±1,02	—	—	—	—	—	—	—	—	—
11	0,28 ±0,03	23,38 ±0,13	38,00 ±1,32	0,31 ±0,03	24,25 ±0,26	35,86 ±1,51	0,23 ±0,03	23,75 ±0,39	14,00 ±0,91	—	—	—	—	—	—	—	—	—
12	0,35 ±0,02	19,55 ±0,23	40,50 ±1,12	0,37 ±0,02	21,13 ±0,35	39,33 ±1,24	0,32 ±0,02	17,66 ±0,43	23,71 ±1,02	—	—	—	—	—	—	—	—	—

Note: Stimulated labyrinth is the one, in the horizontal canal of which ampulopetal endolymph flow began under the effect of angular accelerations a dash signifies total inhibition of nystagmus; the first transection was performed on the right in pigeons Nos 4-9 and on the left in the others.

To determine the nature of OO effect on reflexes from SC, one should compare reactions that result from stimulation of SC alone to those arising upon joint stimulation of SC and OO. Yet, as can be seen from the literature [1, 6, 12, 13], reactions that are not indeed of purely canal origin are often viewed as those that are related exclusively to stimulation of SC. The fact of the matter is that, under natural conditions, a stimulus addressed to the SC always acts in the presence of gravity acceleration, a stimulus that is adequate for OO. When delivering a stimulus to OO, the experimenter merely alters a certain base level of their excitation due to the effect of gravity acceleration. For this reason, experiments with stimulation of SC, SC and OO in intact animals merely indicate that there are different results from interaction of SC and OO, rather than how a given effect is obtained.* In intact animals, one cannot deliver isolated stimulation to SC under ordinary conditions, but this becomes possible after exclusion of OO. The results of comparing SC reactions of intact animals to those of animals with excluded OO makes it possible to assess the direction of OO effect on reflexes from SC.**

In experiments involving elimination of OO (utriculi and sacculi simultaneously) by means of rapid centrifugation, a decline in intensity of nystagmus after this procedure was demonstrated [4, 5]. However, the conclusion that there is a link between diminished intensity of nystagmus and exclusion of OO is not indisputable. On the one hand, normal SC function could have been impaired due to hemorrhages and discharge of otolith membranes into SC ampullae, i.e., due to incidental factors that are usually associated with self-centrifugation.*** On the other hand, with this method of excluding OO, not only otoliths, but the entire body are exposed to centrifugal force. The following is indicative of the powerful traumatic effect of this factor on the body: in the experiments of E. V. Lapayev et al. [5], 6 out of 10 animals submitted to centrifugation in order to separate otolith membranes died within 2 h. Moreover, according to Magnus [7], animals with excluded OO presented dissimilar rotatory and post-rotatory reactions of the eyes and head with regard to intensity and intervals after centrifugation, i.e., the initial attenuation of reactions from SC were not necessarily related to exclusion of OO.

The method of exclusing OO by means of severing of neural branches that innervate them is more adequate for solving the problem under discussion. Igarashi et al. [16], in experiments on squirrel monkeys, performed unilateral and bilateral exclusion of OO (utriculus and sacculus on each side) by severing the utricular nerve and destroying the saccular macula. The results of these studies enabled him to conclude that nystagmus was inhibited from SC as a result of exclusion of OO. However, since it is impossible to destroy the saccular macula without damaging the membranous labyrinth, the authors [16]

*In view of change in activating effect of OO and as a result of their stimulation, or due to change in their inhibitory effect.

**In order to answer this question it is necessary for one of the compared groups of reactions to be those of intact animals. Use instead of reactions that occur as a result of severing the nerve of some SC, as was done previously [15, 18] is not entirely valid, since it was shown [17] that exclusion of SC in itself alters reactions from OO.

***The major hemorrhages that occur during centrifugation are in themselves sufficient to exclude labyrinthine function [7].

remark that the observed effects were apparently due, to some extent, to displacement of the endolymphatic system, effect of hemorrhages and changes in biochemistry of endolymph as a result of surgery.

In our experiments, exclusion of OO was not associated with either a traumatic effect from centrifugal force on the body or impairment of integrity of endolymphatic space; for this reason we are apparently entitled to related the demonstrated changes in nystagmus to exclusion of OO.

Our findings indicate that the utricular region has an activating effect on horizontal nystagmus elicited by angular accelerations. The effects of the utriculi are bilateral, but the effect of a utriculus is more marked on the ipsilateral SC than contralateral. The degree of inhibition of nystagmus after exclusion of utricular regions differs individually. In a number of instances there is total inhibition of nystagmus, i.e., it does not occur in spite of SC stimulation.*

The conclusion that utriculi have an activating influence on reflex arcs of horizontal canals is not in contradiction with data in the literature, to the effect that OO stimulation can elicit both intensification of reactions from SC and their inhibition [1, 6, 8, 12, 13], since different interaction results can be obtained by means of raising or lowering a certain base level of activing effect of OO. Evidently, this level changes when otolith membranes shift in relation to the macula.

The submitted data also indicate that the parameters of nystagmus elicited by SC stimulation depend on the state of the reflex arcs related not only to SC but utriculi. Underestimation of this circumstance could be the cause of wrong conclusions about the state of vestibular function when it is tested. For example, differences between responses of the right and left SC are not necessarily related to their functional asymmetry. These differences may be related to asymmetry of OO of both utriculi and sacculi [9, 11]. At the same time, it is easy to imagine a situation, in which functional asymmetry of SC would be compensated by asymmetry of OO function. Such compensation would result in absence of differences in responses upon stimulating the left and right SC. For this reason, one must devote special attention to examination of OO, particularly since their functional asymmetry could not only distort data about the state of SC, but lead to appearance of inadequate reactions [3, 9, 10]. Evaluation of otolith function on the basis of magnitude of reflexes in response to displacement of otolith membranes along the bitemporal axis [14] is not informative enough, since symmetry of reflexes when membranes shift along the bitemporal axis by no means indicates that they are symmetrical upon shifting along the nasooccipital axis. In addition, one must take into consideration the possibility of discrete functional asymmetry of OO [3], for detection of which it would apparently be expedient to use drugs that eliminate or attenuate the corrective influences of higher segments of the central nervous system on vestibular function.

*It should be noted that a similar effect was discovered in experiments on cats: nystagmus appearing due to transection of the horizontal SC nerve was entirely inhibited in some animals after transection of the nerve of the contralateral utriculus [5].

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INDIVIDUAL DIFFERENCES IN MAXIMUM OXYGEN UPTAKE REGULATION AND LEVEL

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[Article by V. S. Gorozhanin]

[English abstract from source] Neuronal and hormonal mechanisms responsible for the differences in the maximum oxygen consumption are discussed. The subjects with electroencephalographic and sensory signs of stimulating reticular-hypothalamic-amugdalic effects balanced with inhibitory cortical-striatic-septic-hippocampal-epiphyseal effects showed a high oxygen consumption, moderate excretion of epinephrine and norepinephrine, moderate plasma concentrations of ACTH, cortisol, total and free 11-OHCS and insulin, relatively high concentrations of STH, as well as specific dynamics of hormonal and metabolic reactions to aerobic effects. They included a moderate increase of the excretion of dopamine, DOPA and plasma concentrations of ACTH, a comparatively stable level of cortisol, total and free 11-OHCS, drastic increases of norepinephrine excretion and STH, lactate and pyruvate concentrations, a moderate decrease of insulin and pH levels. The subjects with high hypothalamic-reticular-amygdalic effects exhibited an opposite type of endocrine activity and time-course variations of hormonal-metabolic parameters, as well as low values of oxygen consumption.

[Text] Maximum oxygen uptake (MOU), which determines maximum oxygen supply, is one of the most important integral characteristics of the human body, and it determines the level of physical work capacity, endurance [1, 8, 10, 13], general health status, resistance to hypoxia, hypothermia and hyperthermia, and other extreme factors [2, 8]. It has been shown that a rise in MOU level is associated with acquisition of functional distinctions that provide for higher human tolerance to various extreme factors, so that it can be used as an integral criterion for assessing the functional state of man [2]. In recent times, determination of MOU is used in astronaut screening in the United States [11].

It is common knowledge that there is high interindividual variability of MOU, which is related to conditioning, age, sex [1, 8, 10, 13] and individual

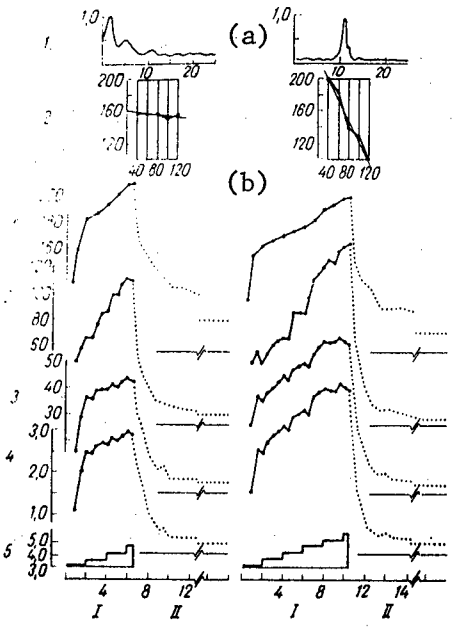
genetically determined distinctions [16]. Thus, extremely low MOU--32.2 mℓ/kg•min [15]--are recorded for unconditioned male Hindus 20-30 years of age who lead an active life, whereas in nonathletic Swedes 20-25 years of age MOU is 60-62 mℓ/kg•min [10], which is comparable to levels inherent in world class skiers and marathon runners (70-80 mℓ/kg•min) [10, 13] and the record MOU (94 mℓ/kg•min) [12]. The reasons for such differences have not been found.

We submit here the results of studies, in which the individual level of human MOU is considered as the result of distinctive organization of the nervous and endocrine systems.

Methods

We studied 59 men 18-28 years of age (VUZ students not involved in sports). The EEG was recorded monopolarly in 8 leads with placement of electrodes by the 10-20% system. Its frequency analysis was made using analyzer-integrators with distinction of 5 rhythms: δ (1-4 Hz), θ (4-8), α (8-13), β 1(13-20), β 2(20-30), for each of which we determined amplitude integrated per 10 s (hereafter arbitrarily referred to as "energy"). We determined on a digital computer the standardized energetic spectral densities of the EEG with use of rapid Fourier conversion. We measured time of reaction (RT) to audio signals on 5 levels of volume: 40, 60, 80, 100 and 120 dB at a frequency of 1 kHz (baseline) and absolute electrodermal thresholds by the "border" method. RT changes were assessed according to values for the RT_{40}:RT_{120} ratio (where RT_{40} and RT_{120} are arithmetic means of 20-25 measurements of RT to sounds of 40 and 120 dB, 1 kHz) and coefficient b in the regression equation $y = a + bx$, which approximates an empirical broken RT to stimuli on 5 levels of volume. According to the results of testing 9400 people, the range of fluctuation of these 2 parameters is 0.79-2.55 and +0.29- -2.24, respectively [4]. All procedures were described in detail previously [4, 5]. The subjects were divided into 2 polar groups: the 1st consisted of 28 men with high energy of δ and θ rhythms on the EEG, low energy of α rhythm, low thresholds, RT_{40}:RT_{120} and coefficient; the 2d consisted of 31 men with the opposite characteristics (Figure). Height and weight constituted 171±0.8 cm and 68.2±0.4 kg, respectively for subjects in the 1st group, 174±0.5 cm and 65.8±0.3 kg in the 2d.

Gasometric parameters were determined using automatic gas analyzers with digital print-out of data after 30 s. A load was given in the form of running on a treadmill, where the velocity of the belt was increased by 0.5 m/s every 2 min. All parameters, which included heart rate (HR), were measured while running and for 30 min in the recovery period (see Figure). Conventional parameters [1, 8, 10, 13] served as criteria of reaching MOU. Blood samples drawn from the ulnar vein 2 h before the treadmill test and after it for assays of concentrations of adrenocorticotropic (ACTH) and somatotropic (STH) hormones, cortisol and insulin by radioimmunological methods, levels of total and free 11-hydroxycorticosteroids (11-HCS) were assayed by spectrofluorimetry [9]. Concentrations of lactate, pyruvate and glucose, as well as blood pH, were determined before the test and in the 3d and 30th min of the recovery period. Excretion of epinephrine (E), norepinephrine (NE), dopamine (DA) and dopa was determined by spectrofluorimetry [9]. All analyses were made in the mornings.



Examples of changes in tested characteristics of the two groups of subjects

a) plots of spectral densities of EEG and changes in RT for stimuli on 5 levels of volume for 2 subjects from 1st (left) and 2d (right) groups
   1) plots of standardized energetic spectral densities of EEG (averaged for O_1 and O_2 leads--left and right occipital regions). X-axis, EEG frequency (Hz); y-axis, spectral densities (relative units)
   2) plots of changes in RT for audio signals on 5 levels of volume. X-axis, volume dB level (in Hz); y-axis, RT (ms)

b) dynamics of gasometric parameters and HR of same subjects while running on treadmill (I) and after 30-min recovery period (II). Top to bottom:
   1) HR (per min)
   2) pulmonary ventilation (ℓ/min)
   3) relative O_2 uptake (mℓ/kg•min)
   4) absolute O_2 uptake (ℓ/min)
   5) treadmill belt velocity (m/s)
   6) time scale, min

Results and Discussion

The results are listed in Tables 1 and 2. Higher values were recorded for the 2d group of subjects for MOU, pulmonary ventilation, CO_2 output, utilization of O_2, O_2-pulse, energy production, oxygen debit and, conversely, lower values for the respiratory quotient, ventilation equivalent for O_2 and HR upon reaching MOU. Typical differences were also found between parameters for the 1st and 2d groups of subjects in baseline concentrations of hormones and neurotransmitters, as well as dynamics of hormonal-metabolic reactions to the physical load. The 1st group presented statistically reliable increase in excretion of E and plasma concentrations of ACTH, cortisol, total and free 11-HCS, insulin and decrease in concentrations of STH, lactate and pyruvate. Conversely, in the 2d group of subjects, E excretion and concentrations of ACTH, cortisol, total and free 11-HCS, insulin were lower, while STH, lactate and pyruvate were higher. The 1st group reacted to the test with a marked elevation of E excretion with drastic decline of NE excretion and statistically reliable drop of DA excretion without changes in dopa excretion, drastic increase in concentration of ACTH, cortisol, total and free 11-HCS of plasma, some increase in STH concentration and marked decrease in insulin concentration, less increase in peak concentrations of lactate, pyruvate, tendencies toward rise in glucose level and drastic decline of blood pH. The subjects of the 2d group responded to the test in the opposite way. In the 30th min after the test, concentrations of ACTH, cortisol, 11-HCS and lactate remained significantly elevated, while pH remained low in the 1st group, which was indicative of minimal recovery.

It has been shown [4, 5], that high values for energy of Δ and Θ rhythms on the EEG combined with low values for sensory thresholds, as well as RT_{40}:RT_{120} ratio and coefficient b, reflect the special organization of the nervous system: variant 1 with prevalence of activating influences of the reticular system of the mesencephalon and stem, hypothalamus and amygdaloid complex over

Table 1. Electrophysiological, sensory and cardiorespiratory parameters of subjects ($\bar{X}\pm MX$)

No	Parameter	Group of subjects	
		1	2
1	EEG delta rhythm energy, μV•s	73,3±1,2	37,1±1,0
2	EEG theta rhythm energy, μV•s	61,0±1,3	35,5±0,9
3	EEG alpha rhythm energy, μV•s	57,5±3,7	187,4±8,1
4	EEG beta-1 rhythm energy, μV•s	35,1±0,8*	32,9±0,7*
5	EEG beta-2 rhythm energy, μV•s	33,0±0,8*	31,6±0,6*
6	Tactile electrodermal threshold, V	1,22±0,1	11,3±0,3
7	TR to sound of 40 dB 1 kHz, ms	154±2,1	209±2,4
8	Same for 120 dB, 1 kHz, ms	130±3,2	122±2,0
9	$TR_{40}:TR_{120}$ ratio	1,19±0,01	1,72±0,01
10	Coefficient *b*	0,21±0,01	1,16±0,01
11	Absolute MOU (STPD), ℓ/min	2,88±0,07	3,49±0,06
12	Relative MOU (STPD), mℓ/kg•min	42,4±1,1	53,1±1,0
13	Pulmonary ventilation (BTPS), ℓ/min	111±2,0	119±2,2
14	CO_2 output (STPD), ℓ/min	3,24±0,1	3,78±0,1
15	O_2 utilization, %	3,09±0,05	3,71±0,04
16	Respiratory quotient	1,12±0,01	1,08±0,01
17	Maximum energy production, kcal/min	14,4±0,2	17,5±0,1
18	Same, cal/kg•min	211±3,2	266±3,0
19	HR during MOU per min	201±0,9	194±0,8
20	O_2 pulse, mℓ/beat	14,7±0,2	18,0±0,1
21	Ventilation equivalent for O_2	37,2±0,4	34,1±0,3
22	Oxygen debt, ℓ	5,88±0,1	6,62±0,3

Note: Differences between parameters of the groups are statistically reliable with significance of $P<0.01$, with the exception of parameters Nos 4 and 5 (marked with asterisk).

inhibitory influences of the neocortex, stratum, septohippocampal system and epiphysis, whereas the opposite nature of electroencephalographic and sensory parameters corresponds to variant 2 of nervous system. The first system is characterized, even at relative rest, by a high level of activation, high density of impulsation from activating structures that exceed the flux density from inhibitory structures, "harder" interstructural associations and less flexible regulation of adaptive reactions. Variant 1 nervous system corresponds to an endocrine system with elevated activity of the sympathoadrenal and hypophyseoadrenal systems, insular system and relatively low activity of the hypophyseo-thyroid system and gonads; variant 2 of nervous system corresponds to an endocrine system with opposite organization [5].

Physical loads lead to even more distinct functional differences between the two types of nervous and endocrine systems. In the 1st group of subjects there is close to maximum increase in "power" of reticulo-hypothalamo-amygdaline influences and, consequently, considerable increase in excretion of E, concentrations of ACTH, cortisol, 11-HCS, combined with drastic decrease in excretion of NE and, partially, DA, greater decline of insulin content and some elevation of STH. In the 2d group, which responded to the load with opposite dynamics of hormonal reactions, there was lower "power" of reticulo-hypothalamo-amygdaline influences. Postexercise decline of NE and DA excretion (demonstrated in 2-h batches of urine), along with some elevation of STH and drastic decline of insulin with load in the 1st group is attributable

to the effects of high concentrations of ACTH and corticosteroids. The latter stimulate activity of dopamine-β-hydroxylase and phenyl ethanolamine-N-methyl transferase, which catalyze conversion of DA to NE and NE to E, inhibiting activity of catechol-O-methyl transferase which is involved in breakdown of NE and E [7]. In addition, they inhibit STH synthesis [3] and, together with E and NE, depress insulin secretion [3]. The lower peak concentrations of lactate in the 1st group of subjects are apparently related to low blood pH, since decline of pH of blood and muscles inhibits anaerobic glycolysis and diffusion of lactate into blood [18].

Table 2. Dynamics of hormonal-metabolic parameters with physical load in 1st and 2d groups of subjects ($\bar{X}\pm MX$)

No	Parameter	Group of subjects					
		1			2		
		before test	test	30-min recovery	before test	test	30-min recovery
1	E excretion, ng/min ng/min	6,8±0,9	19,4±1,2		5,2±0,8	14,5±1,1	
2	NE excretion, ng/min	7,1±0,8	1,5±0,4		8,0±1,1	22,1±1,9	
3	DA excretion, ng/min	533±11,2	501±10,8		568±10,5	607±12,0	
4	Dopa excretion, ng/min	8,6±1,1	9,4±1,3		11,4±1,0	18,5±1,2	
5	Plasma ACTH, pg/mℓ	81,4±2,7	331±5,2	92,7±2,8	55,1±2,3	275±4,6	63,3±2,5
6	Cortisol, μg/100 mℓ	11,7±0,3	18,8±0,5	17,9±0,5	9,2±0,4	10,4±0,3	11,1±0,4
7	Total 11-HCS, μg/100 mℓ	21,2±0,6	28,6±0,8	26,8±0,9	16,1±0,4	19,3±0,5	19,0±0,6
8	Free 11-HCS, μg/100 mℓ	4,9±0,1	7,5±0,2	6,6±0,2	2,4±0,1	2,9±0,1	2,8±0,1
9	STH, ng/mℓ	1,9±0,2	7,3±0,6		2,8±0,3	12,4±0,7	
10	Insulin, μU/mℓ	22,1±0,5	8,1±0,4		17,0±0,4	11,8±0,3	
11	Lactate, mg/100 mℓ	10,5±1,0	96,1±2,2	39,4±1,5	16,3±1,6	105,5±2,4	28,6±1,7
12	Pyruvate, mg/100 mℓ	0,77±0,03	2,0±0,04	1,08±0,04	0,85±0,02	3,1±0,05	1,01±0,03
13	Blood pH	7,37±0,003	7,09±0,004	7,26±0,003	7,35±0,002	7,19±0,003	7,32±0,002
14	Glucose, mg/100 mℓ*	85,4±0,8	88,9±0,9	86,7±0,9	82,6±0,7	79,4±0,8	83,4±0,8

Note: Parameters Nos 5-10 were analyzed in 46 subjects. Intergroup differences before, during and after the test are statistically reliable ($P<0.05$), with the exception of parameter No 14 (marked with asterisk).

The results of this study agree with the conclusions in [6], where it was shown that subjects with high energy of δ and θ EEG rhythms and low α rhythm energy are notable for extremely low tolerance to altitude decompression: they developed severe pain symptoms, drastic worsening of efficiency of attention

and longer RT; for subjects with high energy of EEG α rhythm, there is typically very high tolerance to altitude decompression.

Our findings, like the results of other studies of the role of hormonal control of energy supply during physical exercise [3, 7, 14, 17], enable us to conclude that maximum aerobic "power" of man is under the immediate control of neurohumoral and hormonal mechanisms. Individual differences in organization of the nervous and endocrine systems, as well as in dynamics of hormonal and metabolic reactions to exercise, are factors that directly determine differences in MOU. We can distinguish the following set of hormonal mechanisms that lead to high MOU: 1) moderate working concentrations of E, ACTH, cortisol and 11-HCS, and high concentration of the "homeostasis hormone" NE lead to optimum rate of glycogenolysis, high minute volume, stabilization of HR and intensification of lipolysis, since NE stimulates lipolysis, utilization of O_2 and bradycardia without affecting glycogenolysis [7, 9]; 2) moderate decline of insulin concentration limits glycogenolysis, since one of insulin's functions is to block glycogenolysis [3]; 3) high working concentrations of STH stimulate lipolysis and oxidation of fatty acids, reducing glucose utilization by muscles and lowering the respiratory quotient [3].

The second factor involved in MOU differences is the difference in "power" of neurogenic influences on muscles. In the 1st group, the high power of reticulo-hypothalamo-amygdaline influences and high density of impulsation flux to motoneurons of muscles includes many high-threshold, rapidly contracting muscle fibers with high rate of glycogenolysis and low aerobic potential. For this reason, one demonstrates low utilization of O_2, high HR, low blood pH and MOU. In the 2d group of subjects, the power of the reticulo-hypothalamo-amygdaline influences and density of impulsation flux to motoneurons are considerably lower. In such conditions, there is predominant activation of low-threshold oxidative, slowly contracting and intermediate fibers with low rate of glycogenolysis, which leads to increased utilization of O_2, lower HR, higher blood pH and high MOU. As we have shown previously [4], amplitudes of EMG's of the upper and lower limbs, which reflect the "power" of supraspinal influences on the motoneuron system, are several times greater in subjects with variant 1 nervous system than those with variant 2.

These two mechanisms of MOU (hormonal and neurogenic) are apparently interrelated and supplement one another during physical exercise.

The relationship we demonstrated between MOU level and individual distinctions in organization of the nervous and endocrine systems, which are genetically determined characteristics [4, 5], confirm the view that there is marked genetic determination of MOU [2, 10, 16], and it enables us to comprehend the existence of such determination. Considering the simplicity and ease of recording the EEG and sensory parameters we used and their close relation to level of maximum aerobic "power," in our opinion these parameters can be used as criteria for preliminary prediction of possible MOU levels and tolerance of man to hypoxia and other extreme factors.

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SIGNIFICANCE OF VESTIBULAR RECRUITMENT AND DIRECTIONAL DOMINANCE OF NYSTAGMUS IN DIAGNOSTIC TESTS

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[Article by M. M. Levashov]

[Text] Vestibular recruitment (VR), a phenomenon of impairment of vestibular nystagmus as a proportionate function of force of stimulus, is of diagnostic interest in symptomatology of noninflammatory pathology of the ear. In spite of the fact that this phenomenon drew the attention of researchers long ago, there is still no generally accepted opinion about the mechanisms of its onset; there is no uniformity of techniques for its detection and quantitative evaluation, as well as terminology. Since our only purpose here was to try to present in a simplified form the conceptions of mechanisms and potential relevance of this phenomenon to applied vestibulometry, which developed on the basis of our own experience with nystagmometric investigations, this article does not contain a survey of existing views on the genesis and diagnostic value of VR.

First, we should discuss some general theses. VR is demonstrable with use of stimuli that differ in intensity. Both right and left nystagmus must be recorded with each gradation of the stimulus, and all reactions must be assessed in intensity. There must be at least three gradations of the stimulus, since a plot of nystagmus as a function of strength of stimulus is the end result of the study. Let us take three arbitrary gradations of the stimulus--mild, moderate and strong. We shall proceed from the idea that under normal conditions the stimulus is a proportionate function of nystagmus and that the points on the plot corresponding to the three reactions in one direction are situated on a straight line. We shall also consider that, under normal conditions, the plots of responses to the right and left coincide entirely, while a deviation from this rule is a sign of vestibular dysfunction. Incidentally, let us note that coincidence of the plots should not be considered a reliable sign of well-being. Presence of VR is determined from the shape of the graph. If the slop of the curve in the segment between moderate and strong stimuli is steeper than between weak and moderate, one generally refers to VR. In the reverse case, when there is prevalence of steepness in the beginning of the plot and there is no further increment in intensity of nystagmus with change from a moderate to strong stimulus, one refers to vestibular decruitment. In other words, with both recruitment and decruitment

the graph has the form of a broken line, and only the direction of the break differs. This is a simplified scheme constructed with consideration of several assumptions, and it is necessary as the foundation for further constructions.

Let us imagine that each pair of reactions in a different direction to a stimulus of the same intensity (i.e., a pair of points situated on different graphs in the same vertical section) is to be tested for symmetry. In general, asymmetry can be expressed with the formula $A = (R - L)/(R + L)$, where R and L are characteristics of reactions to the right and to the left. If the results of a rotation test are to be evaluated, P could refer to intensity (for example, mean velocity of slow component at the culmination point) of nystagmus directed to the right and L, the same for nystagmus directed to the left. If it is necessary to evaluate the results of a bithermal test (BT), the procedure for evaluating symmetry, which remains basically the same, differs somewhat in its details, since it is four and not two reactions that result from the BT. The asymmetry of reactions in different directions demonstrated with the BT is designated by different terms, among which we prefer "directional dominance" (DD). Although the asymmetry demonstrated with the BT of reactions in different directions is not usually analogized to asymmetry for angular acceleration, there is no basic difference between these forms of asymmetry: they correspond entirely to one another in meaning. This is important and merits more comprehensive discussion.

The results of BT, which consists of four caloric tests (hot and cold for each ear) are evaluated by calculating differences between pairs of reactions. In order to obtain comparable results, one generally uses relative values, for which purpose the difference is divided by the sum of intensities of all four reactions. Comparing a pair of reactions obtained upon stimulation of the right labyrinth to reactions to stimulation of the left, one calculates the parameter of labyrinthine asymmetry (LA), which reflects the difference in labyrinthine reactivity. A similar procedure is used to compare heat reactions to cold ones in order to find the parameter of efficacy of thermostimulation (ET). Finally, by calculating the difference between reactions to the right and left one finds parameter DD. To find DD, one calculates the difference between sums of intensities of reactions in each direction. In assessing reactions to the right using the above formula, calculation is made of the sum of intensities of heat nystagmus induced by stimulation of the right ear and cold, obtained with stimulation of the left ear. This sum of intensities of two nystagmic reactions can be viewed as the qualitative equivalent of intensity of nystagmus, in the formation of which there is concurrent involvement of ampullopetal cupuloendolymphatic change in the right horizontal canal and ampullofugal shift in the left. Such conditions are generated during rapid clockwise rotation. An analogous approach can be used to assess reactions to the left, obtained with the BT with heat stimulation on the left and cold, on the right. The sum of intensities of these reactions corresponds well to the intensity of such nystagmus, which appears upon rapid counterclockwise rotation.

The obvious similarity of DD obtained as a result of BT and asymmetry of reactions to angular acceleration warrant disucssion of the question of relevance of the latter to diagnostication from the same vantage point as for DD in the BT. It is known, that DD is not a rarity in the BT. Presence

of DD is usually viewed as a sign of vestibular system dysfunction. However, until recently the diagnostic relevance of this sign was insignificant since it was impossible to determine either the side of lesion or level of its localization according to DD. We should add that the absence of DD does not rule out dysfunction. The situation could be changed somewhat for the better if we do not limit ourselves to measurement of asymmetry only in the case of one intensity, but gain information about how asymmetry is related to the stimulus. In other words, it would be desirable to obtain a series of DD values under conditions where stimulus intensity changes. We mentioned above that expressly such conditions help demonstrate recruitment (or decruitment).

Investig tion of VR and DD constitute a single problem. The very possibility of a phenomenon such as recruitment indicates that DD cannot be considered a sign that does not depend in any way on intensity of a stimulus. From this point of view, the VR phenomenon is, in turn, a special case of DD, namely the one where the latter obviously depends on the stimulus. One should always consider the possibility of recruitment in diagnostic vestibulometry. For example, one can rule out asymmetry of reactions to angular acceleration only with use of a series of stimuli differing in intensity. Readings taken at only one level of stimulus intensity are insufficient, since it may be that the reaction is symmetrical with expressly such a stimulus, in spite of presence of dysfunction. Since there may be a pressing need to deliver numerous stimuli, the sinusoid rotation test merits special attention. Finally, since all of the latest information pertaining to DD is also important to VR testing, it would be useful to combine the recruitment test with BT, and it is expedient to assess the results of the latter on the basis of a new diagnostic model [1].

The description of the model has been published in detail, so that we shall merely mention its main qualitative features to the extent needed for further discussion of DD. The model is based on data from experimental and clinical nystagmometry. Afferent flow (AF) as a function of stimulus is reflected in the form of an S-shaped curve. There is a rectilinear segment in the central region of the curve, within which there are changes in afferentation with a standard BT stimulus under normal conditions. Addition to this basis of some elements reflecting the level of activity of the complex of vestibular nuclei in the presence of various forms of pathology, as well as presentation of each nystagmic reaction as the result of interaction between two levels of activity (on the right and left), made it possible to gain a graphic idea of formation of different concrete results of diagnostic BT's. The energy level (EL) of each nuclear complex is represented in the model by a graph that reflects AF traveling to the nuclei over the nerve and a certain intrinsic activity (IA) in the nuclei. The slope of each AF curve and baseline difference between two EL's serve as parameters of the model. Pathology is represented in the model by a change in slope and/or linearity of the AF curve, as well as change in IA. Compensation of vestibular dysfunction is reflected by redistribution of IA among nuclei on the right and left which equalizes the two EL's. The intensity of each nystagmus is equated to the difference in coordinates of two EL's with a given BT stimulus. Formulas for calculating parameters of the model supplement its graphic representation. The parameters have been studied statistically,

so that by analyzing the results of a real BT one can gain information about the nature of vestibular dysfunction, presence of compensation or level of decompensation, origin of LA and DD, as well as assess the reliability of difference from normal of the demonstrated deviations. We shall mention here only the qualitative aspects of the model having a bearing on our topic. Since any asymmetry is similar with DD in the BT in vestibulometric tests with use of angular accelerations, the model is also useful for determining the origin of asymmetries detected in the rotation tests. To explain this, let us first discuss the new conceptions of origin of DD in the usual BT. The fact of the matter is that the model enables us to gain a rather plausible explanation of several distinctions inherent in the DD phenomenon, which had been described previously in the literature many times but never explained. Heretofore, it was incomprehensible, for example, why the direction of DD does not agree with the direction of LA, or why changes in one parameter are not in agreement with those of another in repeated tests on the same patient. The model shows that the direction and magnitude of DD depend largely on extent of compensation and for expressly this reason there can be different variants of DD (even DD = 0) with the same form of AF disturbance.

Proceeding from the conceptions upon which the model is based, one can assess the origin of DD by comparing the directions of three diagnostic parameters, LA, ET and DD itself. The origin of DD (regardless of direction) can be considered purely central only when LA = 0 and ET = 0. Let us note that in this case there are no conditions for occurrence of recruitment.

If ET $\neq$ 0 with LA = 0, it is impossible to determine the origin of DD, since the model is designed only for unilateral forms of vestibular dysfunction. If ET = 0 and LA $\neq$ 0, the coincidence of LA and DD directions is indicative of peripheral origin of DD. If the directions do not coincide, central origin of DD is the most probable. There are no conditions for occurrence of recruitment.

According to the model, in cases where LA $\neq$ 0 and ET $\neq$ 0, there is impairment of curve linearity, i.e., deformation of the plot of AF as a function of stimulus: with ET>0 there is nonlinearity in the cold part of one of the curves and with ET<0, in the warm part. In such situations, DD (and consequently, recruitment also) is always of peripheral origin, although one cannot rule out entirely some involvement of central mechanisms. Some idea can be obtained about the details, by virtue of which a given concrete situation developed, by comparing directions of LA and DD. For example, since ET>0 indicates deformation of the cold segment of one of the two plots, a combination of this feature with LA<0, which indicates prevalence of left labyrinth reactivity, is indicative of nonlinearity of the right AF curve. With LA>0, one should think of nonlinearity on the left. Use of an analogous approach to evaluation in the case of ET<0 enables us to conclude that with LA<0 the peripheral origin of DD is attributable to nonlinearity in the warm part of the right curve, and with LA>0, the left one.

All of the above refers to the matter of DD origin in some case or other, but does not deal with the magnitude and direction of DD, since they are largely dependent on level of compensation. The question of compensation is considered comprehensively in the model: baseline difference in nuclear energy levels on the right and left serves as the parameter that determines decompensation. Expressly changes in this difference cause the seeming independence

of DD from other BT parameters (for example LA), which was observed by many researchers.

Of course, making models always involves some assumptions and limitations, and this must be taken into consideration in analyzing VR. Nevertheless, considering that the model yields an idea that is not very distorted about the mechanism under study, the above observations enable us to gain new information about recruitment. The following is believed to be the most important conclusion: since very specific conditions (LA $\neq$ 0 and ET $\neq$ 0) are required for occurrence of the recruitment phenomenon, the origin of this phenomenon is attributable to impaired linearity of AF curve in the nerve, i.e., it is initially related to damage to the receptor system of the labyrinth or impaired conduction of the vestibular nerve.

Now that we have described the relevance of BT to investigation of VR, we should dwell on the question of extent to which the VR phenomenon can, in turn, be important to the study of caloric reactions in the BT. The most significant flaw of the BT is that it furnishes information about responses of the tested system only to a stimulus of strictly fixed intensity. For this reason, whatever the responses to stimuli of other intensities (for example, to irrigation with fluid, the temperature of which differs from body temperature by 6, 5, 4°C), one can only make conjectures proceeding from the assumptions made in the model. The model enables us to find three coordinates of the plot of activity on the involved side: resting level (without stimulation) and levels corresponding to states with standard stimuli--cold and hot. This is quite sufficient if linearity of the curve is not affected. Otherwise, one can determine only the approximate form of the plot. Moreover, as was noted, DD is not necessarily demonstrable always, even when conditions are present for it to occur. This is related, on the one hand, to the small number of coordinates and, on the other hand, to dependence of DD on initial (baseline) correlation between two nuclear complexes. In other words, uncertainty is possible in the BT. By comparing the BT results to data from the sinusoid test, provided several gradations of the stimulus are used in the latter, one can reduce the uncertainty. A good modification of the test is one that consists of a series of tests differing in amplitude of turn of the table with a stable period. Let us call this a stepped sinusoid test. Several nondamping oscillations of the table [stand] within the limits of each test make it possible to assess quite accurately the symmetry of reactions in different directions with a stimulus of the same intensity. After a certain pause, another test is performed that differs in angle of turn, and symmetry of reactions is assessed also. A series of tests yields a graph of nystagmus as a function of stimulus intensity (for reactions in each direction), as well as a graph of the corresponding asymmetry as a function of stimulus, from which one can determine some details that remained elusive in the BT. A comparison of BT results to those of the stepped test helps define the shape of the AF plot when linearity is impaired. Of course, when analyzing the results one must bear in mind the fact that angular acceleration affects both labyrinths. In addition, we have not succeeded as yet to determine the quantitative relationship between caloric and rotatory stimuli, which is needed for precise reconstruction of AF graphs, from the results of nystagmometry. However, one can obtain rather satisfactory and qualitative coincidence of results of the sinusoid stepped test demonstrating recruitment with model representation of the nature of dysfunction as demonstrated with the BT. In

particular, such an approach has proved itself entirely in solving problems of detecting discrete forms of vestibualr dysfunction, which are being worked on at the Leningrad Scientific Research Institute of the Ear, Throat, Nose and Speech. Thus, the new conceptions of VR are entirely justified in diagnostic studies, and in the theoretical aspect they help understand the complex mechanisms of this interesting phenomenon.

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MINIATURE PIEZOELECTRIC TRANSDUCER WITH ELASTIC SHIELD FOR DYNAMIC STUDIES OF BIOLOGICAL OBJECTS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 19, No 5, Sep-Oct 85 (manuscript received 31 Dec 83) pp 81-82

[Article by L. G. Simonov, G. A. Drobakhin, Yu. S. Ioffe, Yu. S. Safarov and Ye. G. Talalayev]

[Text] Ultrasonic techniques have gained wide use in biology and medicine; however, some traditional methodological procedures must be modified to solve biomedical problems of investigation of extreme states.

In preparing for ultrasonic examination of biological objects, in order to provide reliable acoustic contact (absence of air layer or air bubbles) betwene the transducer and subject's body, the site of contact is irrigated profusely with vaseline oil or other compound that produces acoustic contact [1-3], and the sensor is held in the hand during the study [4, 5].

However, it should be noted that the need to use liquid lubricants narrows the area of application of ultrasonic method, while manual immobilization of the transducer is acceptable only for brief studies related, for example, to evaluation of displacement or determination of geometric dimensions of different intratissular structures. In this case, there is the danger of exposing the researcher to ultrasound.

Our objective here was to refine a piezoelectric transducer for dynamic tests and develop a nonliquid material to provide reliable acoustic contact between the transducer and biological object. The research task amounted to evaluation of hemodynamic characteristics of the vascular system of the human brain in the course of long-term observations.

Methods

An estimate was made of optimum dimension of the piezoelectric plate, which is 18-20 mm in diameter, for the miniature piezoelectric transducer (MPT) being developed, and this produced on the transducer intensity in a range that precluded the appearance of biological effects (less than 50 mW/cm^2).

During combined work with the MPT, we used an ultrasonic sphygmograph with low (330 Hz) probing pulse frequency. The induction coil contained in the

oscillatory circuit of the ultrasonic transformer was installed in the housing of the apparatus. These technical and design changes lowered substantially the ultrasound dosage (maximum rate at the transducer of no more than 30 mW/cm^2, with efficiency of 0.5) and made it possible to reduce significantly the weight and dimensions of the ultrasonic transducer.

The piezo plate was covered with a quarter-wave matching layer, the reverse side was coated with rubber which had high damping properties and placed in a housing made of material that absorbs well ultrasonic waves (see Figure).

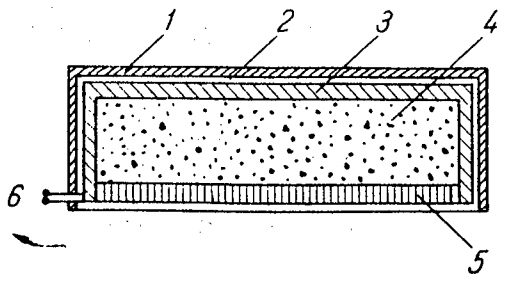

Diagram of MPT
1) outer case
2) epoxy filler
3) inside housing
4) damper
5) piezoplate with matching layer
6) wires

The assembled MPT was placed in a rectangular 33×28×8 mm copper housing (see Figure). Considering the acoustic properties of the tested object (brain, skull), we used a piezoplate with resonance frequency of 1.76 mHz.

During ultrasonic tests requiring manual immobilization of the MPT, before making contact with the biological target, the surface of the sensor was irrigated generously with lubricant in order to provide reliable acoustic contact.

This method of making acoustic contact is unsuitable for prolonged studies, since the transducer is attached to the surface of the biological object and it cannot be moved from the chosen position. For this reason, the need inevitably arises for dynamic studies to restore acoustic contact.

The above considerations concerning the need to expand the area of application of ultrasound (in particular, for biomedical studies of extreme states, when it is possible to provide long-term reliable acoustic contact by means of non-liquid contact material) led us to search and develop a protective material for MPT.

We know of materials used as shields for piezoelectric transducers. They include quartz, beryllium, steel, resin with powder filler (for example, corundum powder), "sitol" and "lingofol" [6]. In industry, for ultrasonic inspection of nonflat surfaces, a material is used which contains epoxy resin, dibutylphthalate and methyltetrahydrophthalate anhydride.

This material (epoxygel-BF) is an irreversible composition that is in a highly elastic state. We tested the physicomechanical properties of epoxygel-BF and the developed material at ultrasonic frequency of 2.5 mHz (Table 1).

Testing of the protective shield revealed that the material of this shield must not only meet the usual requirements for ultrasonic inspection, for example, metal (acoustic transparency, elasticity), but must have additional properties, such as repeated adhesiveness (on the order of 0.5-1.0 kgf/cm^2)

to the biological object and transducer, in order to assure reliable acoustic contact between the piezoelectric transducer and biological object.

Table 1. Physicomechanical properties of shields

Material	Velocity of ultrasound, $m/s \cdot 10^3$	Damping factor, dB/cm	Specific acoustic resistance, $kgf/m^2 \cdot s \cdot 10^6$	Modulus of elasticity, kgf/cm^2
Epoxygel-BF	1.80	1.6	2.16	18.0
Material we developed	1.95	1.4	2.30	9.4

The material developed on the basis of epoxy resin has the following proportion of ingredients: ED-20 epoxy resin (14)--100 wt.%, nitrile carboxylated rubber 60-65 wt.%.

This material is produced by hot polymerization and is an irreversible composition. Data on its adhesive strength as compared to epoxygel-BF are listed in Table 2.

Table 2. Adhesive strength of shield materials

Material	Acoustic contact impaired	Adhesive strength, $kg\,f/cm^2$
Epoxygel-BF	When cone of oscillation is over 5-7°	0.1-0.2
Developed material	When cone of oscillation is over 15°	0.5-0.9

A total of 90 people, 40 of whom were submitted to various biomedical tests which involved change in spatial position of the body from 75 to -30° and 50 were patients in a neurosurgical clinic, were examined with the designed MPT and protective shield we developed.

In view of the possibility of repeated attachment, the subjects experienced no discomfort. We did not observe slippage of the MPT with shield during the tests.

The specifications of the MPT and elastic shield made of the newly developed material make it possible to receive signals from the cranial cavity with frontal-occipital probing, with registration of signal reflected from the occipital bone.

A comparison of the results of tests made with use of shield made of the proposed material and without it (acoustic contact made by means of liquid lubricant) revealed that the presence of the shield on the transducer during echolocation does not contribute any additional demonstrable signals.

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VALIDATION OF RELIABILITY OF FIRE EXTINGUISHERS FOR MEDICAL PRESSURE CHAMBERS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 19, No 5, Sep-Oct 85 (manuscript received 12 Jun 84) pp 83-84

[Article by G. Kh. Kharisov and N. F. Bubyr']

[Text] It is known that in case of fire in a medical pressure chamber when it is being operated in the regular mode (i.e., when it contains elevated concentrations of oxygen and high atmospheric pressure), it is impossible to evacuate people, and the only way to save human lives is to extinguish the fire. The design of a fire extinguisher recommended for chambers that can accomodate several people was described previously [1]. In this regard, the question arises as to the level of reliability of fire extinguishers intended for pressure chambers. On the one hand, in case of fire, the life of people in the chamber depends entirely on reliability of operation of the fire extinguisher, so that its reliability must be high. On the other hand, it is known that the reliability of equipment, including fire extinguishers, depends on the cost (cost refers to both capital and operating expenses): the more funds are allocated for production and operation of a product, the more reliable (other conditions being equal) it will be in performing its given functions. Thus, by regulating the reliability of a device one can also regulate its cost. At the present time no standards have been set for parameters of reliability of equipment that protects people from the hazardous factors of a fire.

At the same time, a standard [2] does specify the use of organizational measures and technical equipment for a system of fire prevention that limit human exposure to the hazardous factors of a fire to a probability that does not exceed the standard of 10^{-6} per year scaled to one person.

Omitting proof, we submit here the formulas that permit validation of the reliability level of fire extinguishers in cases where human life, in case of fire, depends entirely on operation of fire extinguishing equipment and the process of extinguishing the fire.

If the pressure chamber is protected with a fire-extinguishing system, the probability of its malfunction Q should not exceed β:

$$Q \leq \frac{1}{N \cdot \lambda \cdot T \cdot 10^{6}} \cdot \beta, \quad (1)$$

where N is the mean number of people present together, around the clock, in a pressure chamber for time T = 1 year; λ is intensity of moments of occurrence of fires in the chambers. Parameter λ can be found from statistical data using the formula:

$$\lambda = \frac{n_f}{K \cdot \Sigma t}, \tag{2}$$

where n_f is the total number of fires that occurred in operating K chambers; Σt is total service life of pressure chambers K in years (including those, in which fires did not occur).

The probability of malfunction Q_1 of a fire-extinguishing system without back-up, i.e., a system that consists of one fire extinguisher, is determined with the formula:

$$Q_1 = \left(\frac{\lambda_d \tau}{2} + \frac{\lambda_o}{\mu} + \frac{\Sigma t_{TO}}{T_{TO}}\right), \tag{3}$$

where λ_d and λ_o are parameters of flow of discrete and overt malfunction of fire extinguisher, respectively; μ is intensity of restoration of work capacity of the fire extinguisher; Σt_{TO} is mean overall duration of maintenance in the technical maintenance (TO) cycle; T_{TO} is the TO cycle (according to GOST 18322-78); τ is time between inspections of serviceability of the fire extinguisher.

If the pressure chamber is protected with two extinguishers, i.e., there is a back-up fire-extinguishing system, probability Q_2 of malfunction of such a system in the case where the two extinguishers are never subject to maintenance simultaneously is determined with the formula:

$$Q_2 = \frac{(\lambda_d \tau)^2}{3} + 2\left(\frac{\lambda_o}{\mu}\right)^2 + 2\left(\frac{\lambda_d \tau}{2} + \frac{\lambda_o}{\mu}\right)\frac{\Sigma t_{TO}}{T_{TO}}. \tag{4}$$

Formulas (1), (3) and (4) constitute the basis for strategy of choice, assurance of required reliability and operation of fire extinguishers designed for protection of human life. Let us analyze these formulas in order to find factors that can be actively influenced in practice. First of all, let us note that, according to formula (1), the more people are in the chamber, the more reliable the fire extinguisher must be. There are two opinions on this score in other countries. Some specialists [3] believe that the allowable risk of hazardous fire factors and subsequent human death should not depend on the number of people exposed to this risk. Others [4], on the contrary, believe that the more people are at risk of simultaneous death, the lower the risk must be. In the cited work, it is believed that the permissible risk of simultaneous death of n people must decline proportionately to n^2 or $k \cdot \ln n$, where k is a certain acceptable coefficient that depends on

many factors. This means that if, for example, 2 people are at risk of death at the same time, this rise must be 4 or $k \cdot \ln 2$ times lower than for 1 person. However, there is still no agreement on this score. The function in formula (1) is inversely proportionate. Formula (1) regulates the level of reliability of a fire-extinguishing system as a function of number of people in the chamber and incidence of fires in pressure chambers: the more people in a chamber and the more frequent the fires, the more reliable the fire-extinguishing system must be.

Formulas (3) and (4) describe reliability of a fire-extinguishing system. If this system consists of one fire extinguisher its reliability is determined using formula (3) and if it consists of two, one uses formula (4). In these formulas, λ_d, λ_o, μ reflect the status and achievements of those sectors of science, engineering and industry that are related to use, design and production of fire-extinguishing equipment. It does not appear possible to influence these factors appreciably when operating fire-extinguishing systems. Parameters τ, Σt_{TO} and T_{TO} depend on the funds allocated for operation of fire-extinguishing systems. In this case, it becomes possible to vary these parameters in such a way as to adhere to the condition stipulated in formula (1) by selecting the most advantageous proportion of terms in formulas (3) and (4), depending on concrete conditions. We shall illustrate evaluation of reliability of a fire-extinguishing system with an example.

Let a medical pressure chamber be delivered for operation, in which there will be an average N = 4 people around the clock for a time T that equals 1 year. In case of fire, it is impossible to evacuate the people and their life depends on operation of a specific fire-extinguishing system which may consist of one or two devices for extinguishing fires with water. The parameters of flow of discrete and overt malfunctions of the fire-extinguisher $\lambda_d = \lambda_o = 0.2$ per year, and mean recovery time for serviceability of the fire extinguisher is t_r = 3 h = 0.000343 year (then the intensity of recovery $\mu = 1/t_r$ = 1/0.000343 = 2920/year), time between inspections τ = 3 months = 0.25 year, mean total duration of maintenance per TO cycle is Σt_{TO} = 72 h = 0.008217 year, and the cycle of maintenance T_{TO} = 1 year. We shall consider the incidence of fires in medical pressure chambers to be $\lambda = 0.0001$ in the operation of 10,000 chambers [as we mentioned above, this parameter must be determined using formula (2) on the basis of statistical data].

We need to determine whether, under these conditions, each fire-extinguishing system with and without back-up can provide for the required safety standard for people.

Solution 1. Using formula (1) we find the maximum permissible probability β of malfunction of fire-extinguishing system:

$$\beta = \frac{1}{4 \cdot 0{,}0001 \cdot 10^6 \cdot 1} = 0{,}0025.$$

2. Using formula (3), we determine probability Q_1 of malfunction of single fire-extinguishing system [without back-up] under the given conditions:

$$Q_1 = \left(\frac{0{,}2 \cdot 0{,}25}{2} + \frac{0{,}2}{2920} + \frac{0{,}008217}{1}\right) = 0{,}033286.$$

Comparing Q_1 and β, and taking into consideration that Q_1 must be smaller than or equal β, we conclude that the nonback-up fire-extinguishing system cannot provide for the required safety of 4 people.

3. Using formula (4) we determine probability Q_2 of malfunction of a fire-extinguishing system with back under the specified conditions:

$$Q_2 = \frac{(0,2 \cdot 0,25)^2}{2} + 2\left(\frac{0,2}{2920}\right)^2 + 2\left(\frac{0,2 \cdot 0,25}{2} + \frac{0,2}{2920}\right)\frac{0,008217}{1} = 0,001234.$$

The fire-extinguishing system with back-up will more than assure the required safety of 4 people under the specified conditions.

4. Adjusting the obtained value for Q_2 in formula (1) and solving this equation for N, we shall obtain the maximum number N_m of people whose safety will be assured by the backed up fire-extinguishing system:

$$N_M = \frac{1}{Q_2 \cdot \lambda \cdot T \cdot 10^6} = \frac{1}{0,001234 \cdot 0,0001 \cdot 10^6 \cdot 1} = 8 \text{ people}$$

Thus, the fire-extinguishing system with back-up can provide the degree of safety required by the standard for each individual, but for no more than eight people at the same time. As shown by the calculations, this fire-extinguishing system can assure the safety of a greater number of people. For this purpose, it is necessary to reduce time τ between inspections of serviceability of the system and mean overall duration Σt_{TO} of maintenance per TO cycle, which can be done by increasing operating expenses. For example, by reducing τ from 3 months to 1 month and Σt_{TO} from 72 h to 24 h (i.e., by increasing operating costs by about 3 times), the fire-extinguishing system with back-up will be able to assure the safety of 72 people.

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BRIEF REPORTS

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AGE-RELATED CHANGES IN ELECTROENCEPHALOGRAMS OF PILOTS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 19, No 5, Sep-Oct 85 (manuscript received 17 Sep 84) pp 85-86

[Article by E.Marks, W. Zuzevic, E. Dworezki and M. Mazenzki (Polish People's Republic)]

[Text] Electroencephalographic examination was introduced into clinical aviation medicine in Poland 25 years ago. It has gained use in both expert examination of candidates for Higher Officer's Aviation School and periodic examination of pilots [1, 2, 7, 8, 10]. As a result of screenings, electroencephalograms (EEG) were collected on the same individuals for almost 20 years. This unusual file made it possible to analyze age-related EEG changes in pilots.

Methods

This study was conducted in two stages. At the 1st stage we performed visual and statistical analysis of 343 EEG of 125 pilots; at the 2d stage, we screened pilots of two age groups: the average age of individuals in the 1st group was 24.7 years (19 people) and in the 2d group, 43.8 years (47 people). We used the method of evoked potentials (EP) in response to photic stimuli.

The average age at the start of EEG observation was 25.1±5.5 years and at the end, 43.6±4.6 years. We analyzed regularity of α rhythm on the EEG, mean frequency of basic rhythm, mean amplitude, reaction delay, activation of EEG by hyperventilation and light flashes (stroboscope), correlation between slow waves, frequency and amplitude of basic rhythm, correlation between EEG and clinical parameters. We used a specially developed chart to analyze the EEG. We used the criteria of Student, Shapiro-Wilke and χ^2 in statistical processing.

Results and Discussion

In the 1st examination, there was prevalence on the EEG of irregular α rhythm (in 60% of the cases). In the last examination, an irregular α rhythm was encountered in only 44% of the cases and β rhythm in 12% (the α rhythm was transformed into irregular β rhythm). Changes in basic rhythm were unreliable.

We demonstrated a statistically significant ($P<0.05$) difference in mean frequencies of basic rhythm: rhythm frequency was 10.1/s in the first test and 9.7/s in the last. The number of EEG's with slow waves increased reliably from 12.8 to 27.2% ($P<0.01$). Slow waves were focal, particularly in temporal leads and less often in the frontotemporal leads of one or both hemispheres. We observed distinct focusing of the slow waves found in the first EEG. There was an increase in number of EEG's with sincipital α waves from 4 to 11.2% ($P<0.05$).

Low-voltage basic rhythm was demonstrable only in isolated cases in the first and last examination.

EEG amplitude, reaction delay, nature of EEG activation with hyperventilation and delivery of flashes did not change. We failed to find an appreciable link between frequency and amplitude or a correlation between presence of slow waves and variability of basic rhythm frequency and amplitude.

Presence of disease or changes related to aging were found in 33 cases.

Slow waves were encountered more often on the EEG of pilots with clinical deviations (16 out of 33 people) than in healthy ones (18 out of 92). A comprehensive analysis of correlation between EEG and clinical parameters turned out to be impossible due to the small number of analyzed cases in the different clinical groups. In one of the larger clinical groups (degenerative deforming changes in the spine) the indicator of changes in the EEG was high (in 11 out of 21 people), but most were already observed at the first examination.

A study of EP failed to demonstrate reliable changes in parameters with age.

A decrease in frequency of α rhythm was found only after the age of 50 years [6]. The decline in frequency of α rhythm begins already at 20 years of age and continues to advanced old age (2000 people were examined). According to the clinical data in [5], pertaining to a screening of 170 people 40-60 years of age, mean frequency of α rhythm was 9.9/s. The decline of α index in the occipital leads is indicative of aging.

The increase in number of EEG's with slow-wave activity reaches a peak in the fifth decade of life [6]. In essence, focal activity is observed in the temporal regions and primarily on the left side. Significant rise in slow-wave activity had been noted at an older age (52.9 years) [5] than in our study--43 years. The share of EEG's with slow-wave activity in our study constituted 27.2% and in the work of other authors, 20-35% [3, 6].

In the material we analyzed, there were no changes in EEG reaction to hyperventilation and photic stimulation, which does not agree with the report of other authors [6] that there was spike activity in 0.2% of the subjects at the age of 30-40 years. This was probably due to the specific distinctions of the group of people we studied.

Examination of EP dynamics in older individuals failed to demonstrate statistically significant changes. A change, with age, in amplitude of P_2

components on the EEG has been reported [4]. Changes in components P_2 and P_3 concurrently with increase in latency period in young people, as well as individuals over 70 years of age, have been observed [9].

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DRUGS AND SURFACTANTS USED TO PREVENT CAISSON DISEASE IN RATS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 19, No 5, Sep-Oct 85 (manuscript received 28 Jun 84) pp 86-87

[Article by V. V. Vlasov]

[Text] Changes in the blood-clotting system and vascular reactions have a substantial effect on rate of gas production, rate of escape of gas through the lungs, size of bubbles and their stability in development of decompression sickness. These reactions are an important factor that determines tolerance to decompression [2]. By altering the body's reaction to the free gas phase that appears in tissues one can deliberately influence tolerance to decompression.

Our objective here was to search for drugs capable of enhancing tolerance to decompression and to investigate the effects of some surfactants (SF) on the course of caisson disease.

Methods

Experiments were performed on white male rats. The animals were placed for 40 min in a pressure chamber at air pressure of 7 kgf/cm^2. Pressure was then dropped to 5 kgf/cm^2 in 20 min, to atmospheric level in 2 min and, after 5-min exposure, to 405 mm Hg in 5 min. At this pressure, we monitored development of the disease for 40 min. Animal tolerance to decompression was assessed on the basis of mortality and severity of disease (scored in points) [6].

Trifluoperazine (5 mg/kg weight), phentolamine (5 mg/kg), raunatin [gendon--Rauwolfia serpentina] (1 mg/kg), novocain (10 mg/kg), diprazin (5 mg/kg), euphyllin (10 mg/kg) and combinations of trifluoperazine, phentolamine, diprazin, euphyllin and novocain (1, 1, 1, 2 and 2 mg/kg, respectively), trifluoperazine, phentolamine and euphyllin (1, 1 and 2 mg/kg), diprazin and novocain (1 and 2 mg/kg) were given prior to the experiment, i.e., 1 h before decompression. The dosage used corresponded approximately to therapeutic levels scaled to body surface. The agents were administered in the same volume (1 mℓ) of isotonic sodium chloride solution intraperitoneally. It has been specially demonstrated that the latter has no effect on tolerance to decompression, in contrast to distilled water and hypertonic solution [5].

Clofibrate, in a dosage of 0.3 mg/kg weight, was used in the form of emulsion in 0.5% aqueous solution of alkylaryl sulfate, which has no effect on

tolerance to decompression. The emulsion was introduced through a catheter into the stomach once a day for 2 days prior to the experiment.

Corticosterone, in a dosage of 0.3 mg/kg, was injected intraperitoneally before the experiment; hydrocortisone, in a dosage of 25 mg/kg, once 4 h before the experiment or twice, 28 and 4 h before the experiment, was infused through a catheter into the stomach, with isotonic sodium chloride solution. Cortisone, in a dosage of 10 mg/kg, was injected into the stomach twice a day for 3 days before the experiment. The animals were given the hormones in 1 mℓ isotonic sodium chloride solution.

SF (sulfonol, alkyl sulfonate C_{18-20}, primary and secondary alkyl sulfates, etc.) were introduced into the stomach in the form of 1% solution at the rate of 2 mℓ/100 g weight 30 min before the experiment.

Results and Discussion

The experimental results are listed in the Table. According to previously published data [5], trifluoperazine had a marked preventive action. Phentolamine had virtually the same effect. Combined use of these agents in lower doses yield a maximum effect. Changes in tolerance to decompression after administration of novocain, diprazin, euphyllin and raunatin were unreliable, but in the same direction. Apparently, the idea of expediency of depressing reactions of cellular elements and proteins of bloods to the gas surface and suppression of spastic vascular and bronchial reactions, on which the choice of agents was based is valid, and a search for agents with analogous action could lead to discovery of new effective drugs. The absence of a reliable effect from single administration of raunatin cannot serve as grounds to abandon further trials of Rauwolfia alkaloids, since their effect depends on dosage and duration of administration.

Administration of clofibrate led to appreciable enhancement of rat resistance to compression. Apparently, this effect should be related to the antilipemic action of the product, which was confirmed in control experiments. Administration of heparin leads to activation of lipolysis and reduction of concentration of lipids in plasma. This is associated with increase in rat tolerance to decompression. Perhaps, it is expressly the hypolipemic, rather than hypocoagulant influence of heparin that determines its preventive and therapeutic effect on caisson disease [1].

In the acute period of trauma, animal tolerance to decompression first diminished and then increased, which can be related to the phases of the body's reaction to trauma [3]. Enhancement of tolerance is apparently attributable to activation of the hypophyseoadrenal system. The increased tolerance after administration of water can slo be related to this [5]. In these experiments, exogenous corticosteroids used in different doses did not enhance tolerance to decompression.

Use of SF for prevention of decompression sickness was successful in a number of studies [4, 8]. Their effect can be attributed to decrease in surface tension, consequent reduction in size of bubbles and their faster dissolution. In these experiments, SF were tried in order to confirm the assumption that administration of SF improves rheological properties of

blood, enhancement of its emulsion stability and limitation of interaction of gas phase with blood proteins with administration of SF [1, 4, 7]. However, no enhancement of animal tolerance to decompression was observed. Absence of SF effect cannot serve as grounds for not testing other surface-active compounds.

Effect of some drugs and SF on development of decompression sickness

Product	Number of rats		Sickness severity		Mortality, %	
	exper.	control	exper.	control	experim.	control
Trifluoperazine	31	28	2,0 ±0,2**	3,5 ±0,2	26 ±8*	50 ±10
Phentolamine	16	26	1,7 ±0,3**	3,0 ±0,2	6 ±5*	35 ±9
Raunatin	13	15	4,1 ±0,4	4,2 ±0,4	77 ±12	73 ±11
Novocain	12	15	3,4 ±0,6	4,2 ±0,4	58 ±14	73 ±11
Diprazin	12	15	3,5 ±0,5	4,2 ±0,4	50 ±14	73 ±11
Euphyllin	12	15	3,8 ± 0,4	4,2 ±0,4	50 ±14	73 ±11
Trifluoperazine+phentolamine+diprazin+euphyllin+novocain	13	15	3,0 ±0,5	4,2 ±0,4	46 ±13	73 ±11
Trifluoperazine+phentolamine+euphyllin	14	15	2,1 ±0,5**	4,2 ±0,4	21 ±11**	73 ±11
Diprazin+novocain	13	15	3,7 ±0,4	4,2 ±0,4	54 ±14	73 ±11
Clofibrate	16	23	2,2 ±0,4**	3,8 ±0,2	25 ±11*	60 ±12
Corticosterone	20	24	2,8 ±0,4	2,9 ±0,3	30 ±10	29 ±9
Hydrocortisone: once	14	26	3,1 ±0,5	3,2 ±0,3	40 ±15	40 ±12
twice	16	25	2,8 ±0,4	3,1 ±0,4	40 ±11	38 ±10
Cortisone	14	28	3,5 ±0,5	3,8 ±0,3	57 ±13	63 ±9,7
Sulfonol	8	24	3,2 ±0,6	3,2 ±0,2	38 ±17	20 ±12
Alkyl sulfonate	8	24	2,5 ±0,5	3,2 ±0,2	13 ±12	20 ±12
Alkyl sulfate: primary	8	24	2,9 ±0,5	3,2 ±0,2	25 ±15	20 ±12
secondary	12	24	3,0 ±0,5	3,2 ±0,2	33 ±13	20 ±12
DNS-A	12	24	3,8 ±0,4	3,2 ±0,2	50 ±14	20 ±12
OP-7 [emulsifying agent]	8	24	2,5 ±0,5	3,2 ±0,2	13 ±12	20 ±12

* $P<0,05$
** $P<0,01$

Thus, the results of the experiments revealed that trifluoperazine, phentolamine and clofibrate are effective means of prevention of caisson disease.

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EFFECT OF 24,25-DIHYDROXYCHOLECALCIFEROL ON AMINO ACID METABOLISM OF HYPOKINETIC RATS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 19, No 5, Sep-Oct 85 (manuscript received 22 Jun 84) pp 88-89

[Article by T. F. Vlasova, Ye. B. Miroshnikova, M. S. Belakovskiy, A. N. Kochetkova and I. N. Sergeyev]

[Text] As it has already been reported [3], 30-day restriction of motor activity of animals against the background of diets differing in calcium and phosphorus content led to decline of amino acid pool of blood, and excessive uptake of phosphorus aggravated the effect of hypokinesia. There is a report in the literature concerning the effect of vitamin D_2 on amino acid composition of blood in rats maintained under ordinary conditions on a standard diet [2]. There are no data on the effect of 24,25-dihydroxycholecalciferol--$24,25(OH)_2D_3$--on amino acid metabolism of animals, but we know that it is desirable to use this compound together with other agents for prevention and treatment of mineral metabolism under hypokinetic conditions [5]. For this reason, we explored the possibility of normalizing amino acid metabolism under hypokinetic conditions with use of diets having a specific proportion of calcium and phosphorus, by means of supplemental administration to animals of an active metabolite of vitamin D_3--$24,25(OH)_2D_3$.

Methods

A Liquimat III (Labotron, FRG, sensitivity of 5 nmol/mℓ) was used to assay free amino acids in rat blood serum, using the method of ion-exchange chromatography [4, 9]. The tested blood serum samples were first deproteinized with crystalline sulfosalicylic acid [8]. Experimental conditions were described previously [1, 5]. Animals submitted to hypokinesia for 30 days were divided into the following groups: 1--animals in whose diet calcium and phosphorus were in a ratio of 1:0.5, 2--1:1, 3--1:2, 4--1:3. The metabolite of vitamin D_3, $24,25(OH)_2D_3$ was given to all groups of animals daily in a dosage constituting the 5-fold physiological dosage of D_3 for rats (0.25 μg/animal). There was a control group, maintained in the vivarium, for each of the above groups of animals. Paramaters were analyzed by comparing them to the control.

Results and Discussion

The Table lists data on free amino acid levels in rat blood serum. The findings indicate that all experimental groups of animals presented changes in

amino acid composition of blood. The 1st group presented hyperaminoacidemia--the amino acid pool in blood increased to 71.4 mg%, versus 59 mg% in the control. Such elevation was due to reliable increase in blood leucine, valine, methionine, phenylalanine and glycine levels in the presence of reduced concentration of proline. Conversely, in the 2d group of animals, total serum free amino acids diminished (50.4 mg% in the experimental group and 63.4 mg% in the control) due to decline of lysine and proline levels. Serum amino acid pool of rats in the 3d group diminished insignificantly (60.8 mg%, versus 62.8 mg% in the control), and we observed increase in concentrations of valine and histidine with decline of leucine level. Finally, in the 4th group of animals, serum free amino acid levels were below control values and constituted a total of 64.9 mg% (73.1 mg% in the control). This decline was due to reduction in concentrations of threonine, tyrosine, proline, histidine and arginine.

Free amino acid levels in blood serum of rats submitted to hypokinesia and kept on diets differing in calcium to phosphorus ratio with administration of $24,25(OH)_2D_3$ (mg%) (n = 4)

Amino acid	Animal group							
	1		2		3		4	
	exper.	control	exper.	contr.	exper.	contr.	exper.	contr.
Isoleucine	1,29±0,17	1,99±0,22	1,82±0,20	2,08±0,33	1,76±0,30	1,70±0,30	1,95±0,14	2,04±0,12
Leucine	2,67±0,24	3,42±0,11*	3,36±0,42	2,89±0,12	3,58±0,12	2,83±0,26	3,93±0,25	3,79±0,11
Valine	1,70±0,17	3,13±0,55*	2,60±0,22	3,09±0,30	1,99±0,17	3,91±0,27*	2,54±0,29	2,70±0,37
Threonine	4,40±0,46	5,17±0,43	5,42±2,24	3,22±0,21	5,88±0,66	4,88±0,37	6,21±0,42	4,95±0,30*
Serine	6,31±1,20	7,93±1,23	4,77±0,32	5,49±0,32	6,46±0,38	5,99±0,11	5,53±0,85	7,18±0,41
Methionine	1,00±0,07	1,56±0,21*	1,11±0,08	1,08±0,20	1,20±0,12	1,29±0,17	1,59±0,19	1,13±0,15
Tyrosine	1,73±0,08	1,96±0,36	1,35±0,05	1,63±0,15	1,72±0,43	1,33±0,11	2,60±0,22	1,75±0,19**
Phenylalanine	0,84±0,11	1,65±0,18*	1,16±0,03	1,22±0,29	1,46+0,15	1,42±0,03	1,39±0,12	1,68±0,30
Cystine								
Aspartic	1,71±0,32	2,24±0,37	2,01±0,28	1,50±0,15	2,27±0,27	1,92±0,08	1,81±0,31	2,19±0,11
Glutamic	3,39±0,53	4,30±0,34	3,73±0,88	2,82±0,25	3,68±0,34	4,21±0,26	3,60±0,32	4,59±0,46
Proline	5,61±0,45	3,74±0,44	5,44±0,30	1,21±0,14*	3,83±0,80	3,80±0,28	6,59±0,62	4,72±0,43*
Glycine	1,72±0,21	2,98±0,35*	2,64±0,53	2,72±0,28	2,42±0,22	2,79±0,11	2,79±0,19	2,58±0,11
Alanine	3,68±0,53	4,35±0,38	4,95±0,22	4,17±0,67	4,70±0,52	4,83±0,41	5,25±0,57	4,36±0,38
Lysine	17,79±1,61	12,17±2,93	18,42±0,62	13,72±1,56*	17,32±1,27	13,65±0,5.	21,01±5,68	17,31±0,66
Histidine	2,17±0,21	2,08±0,25	2,22±0,52	1,55±0,20	1,43±0,28	2,37±0,35	2,87±0,37	1,60±0,51
Arginine	2,95±0,21	3,73±0,60	2,29±0,10	2,02±0,31	3,45±0,35	3,75±0,46	3,40±0,27	2,11±0,11*
Totals	59,0	71,4	64,1	50,4	62,8	60,77	73,06	64,88

*P<0.05, as compared to control.

It was previously shown [3] that, in animals submitted to 30-day hypokinesia on diets with the same proportion of calcium and phosphorus as in this experiment presented decline of blood amino acid pool, and its extent depended on the quantitative ratio of calcium and phosphorus in the diet. These changes were more marked in animals in whose diet calcium and phosphorus were present in a 1:3 ratio. The demonstrated decline of amino acid pool during immobilization was not a chance finding. This is the body's natural reaction to this factor and is elicited by depression of intensity of protein synthesis in tissues [6, 7]. We have established that, when a metabolite of vitamin D_3 is added to the diet there are changes in amino acid status of all groups of animals, and a beneficial effect was manifested only in the 1st group of rats (1:0.5 calcium and phosphorus ratio). Indeed, amino acid equilibrium in blood serum shifted in the direction of increase (12.4 mg% deviation in total amino

acids) not only in comparison to the control, but to the group of animals not given this compound, where the deviation constituted 2.3 mg%. In the 2d group, addition of the metabolite of vitamin D_3 to the diet aggravated the effects of hypokinesia, and the deviation of total amino acids constituted 12.9 mg% in comparison to the control, whereas without the vitamin it constituted 4.2 mg%. In the 3d and 4th groups of animals, the metabolite of vitamin D_3 did not cause appreciable changes in amino acid balance, as compared to hypokinetic conditions on a diet with 1:2 and 1:3 ratio of calcium to phosphorus.

Consequently, use of $24,25(OH)_2D_3$ in a dosage constituting 5 times the physiological dose of vitamin D_3 helps restore the amino acid status, and optimization of calcium and phosphorus content in the diet is a mandatory condition for use of the metabolite for this purpose.

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BIOCIDAL SYNTHETIC COATINGS BASED ON HIGH-MOLECULAR METALOORGANIC COMPOUNDS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 19, No 5, Sep-Oct 85 (manuscript received 24 Jan 81) pp 89-92

[Article by V. F. Mishchenko, V. A. Zubov and Yu. G. Yeremenko]

[Text] Long-term stays of man and animals in closed life-support systems lead to contamination of the room and objects in it by various microorganisms. Use of traditional sterilization methods (ultraviolet irradiation, heat treatment, treatment with disinfectants, etc.) was found to be either ineffective or extremely difficult and unsafe [15]. Use of biologically active paint and varnish is an effective means of preventing development of microorganisms in closed life-support systems [1, 5, 9], when they contain as biocidal supplements low-molecular organic compounds [4, 6, 18], organic derivatives of arsenic [19], lead [2], mercury [21] and copper [11, 13]. However, these materials are often highly toxic for man and animals. Moreover, the low-molecular compounds used as biocidal additives in paint and varnish do not yield the desired result, since this biocidal agents usually do not have a broad spectrum of protective action [10, 12]. Their action is more often specific (selective) [3, 14]. In addition, due to constant exudation, the biocidal agents are utilized unwisely, which ultimately leads to reduction of efficacy and duration of protective action of the coating [8].

Synthetic, biologically active polymers, the biocidal properties of which are due to presence in their structure of biologically active compounds with hydrolytically unstable bonds with the polymer chain, are the best means of protecting materials and equipment in closed life-support systems. Activity of this type of polymers is manifested only when there are favorable conditions for development of microorganisms (high humidity and temperature). A decrease in humidity and temperature "turns off" the mechanism of biocide discharge.

Of the many organic and metalloorganic biocidal agents, organotin compounds should be considered the most promising; they have a broad spectrum of action against various microorganisms, displaying high efficacy in low concentrations and having exceptionally low toxicity for warm-blooded animals and man [2, 16, 20]. In addition, organotin biocidal agents are ecologically safe, since they are converted into harmless tin oxides when exposed to solar radiation [20].

The polymers developed at the present time for this purpose contain a significant amount of organotin biocidal agents--0.5-30 mass% scaled to metal tin [2, 7, 17]. We synthesized several polymers of the (meth) acrylate type (that differ from those described above in that they contain less tin by a factor of 10^2-10^3) in order to develop highly effective, biologically active polymers, and we tested the fungicidal properties of coatings produced on their basis.

Methods

Varnish solutions of organotin polymers were applied with a brush to silicate glass 25×100 mm in two layers and tested for fungicidal activity according to GOST 9.050-80. The thickness of the polymer film was 20-30 μm. The coatings were infected with massive doses of fungi (suspension with 1-2 million spores per mℓ).

We used the following as test organisms: Aspergillus flavus, Aspergillus niger, Aspergillus terreus, Penicillium funiculosum, Penicillium cyclopium, Penicillium chrysogenum, Paecilomyces varioti, Chaetomium globosum and Trichoderma viride.

Czapek-Dox culture medium (pH 6±0.5) consisted of the following: monocalcium phosphate, dicalcium phosphate, magnesium sulfate, sodium nitrate, potassium chloride, ferrous sulfate, saccharose and microbiological agar.

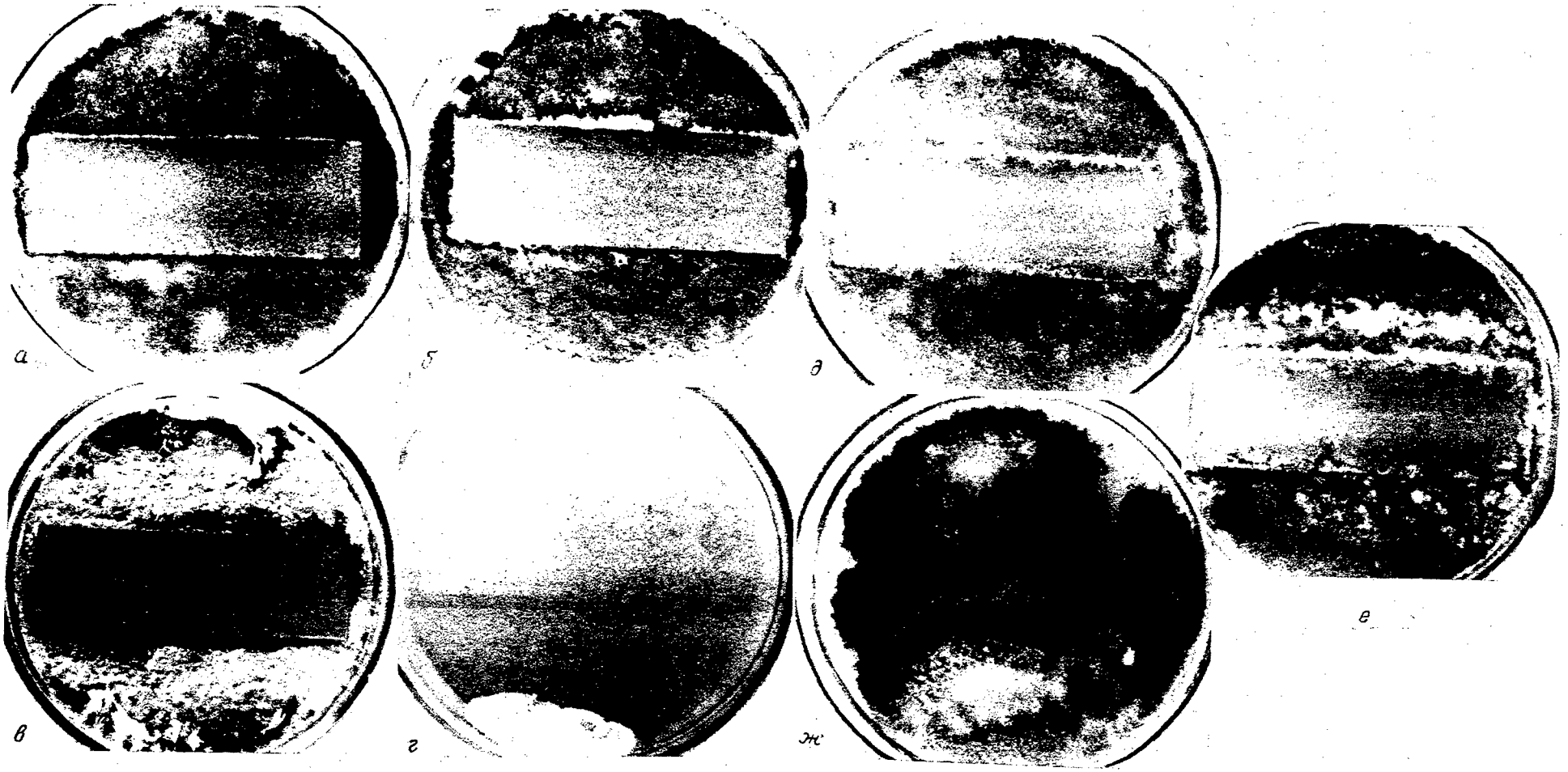
Results and Discussion

The Table and Figure illustrate the results of testing specimens of coatings based on organotin polymers for fungicidal activity.

Fungicidal properties of coatings based on organotin copolymers of the (meth)acrylate type

No.	Fig.	Tin content, mass%	Fungus growth score		Zone of fungus growth inhibition, mm	Feature of coating
			meth.A	meth.B		
1	а	0,0001	1	2	None	Fungus-resistant
2	б	0,001	1	2	»	»
3	в	0,01	0	0	»	Fungicidal
4	г	0,1	0	0	30	»
5*	д	0,1	3	3	None	Fungus-resistant
6**	—	1,0	5	5	»	Not fungus-resistant
7**	е	2,0	5	5	»	» »
8***	ж	0,0	5	5	»	» »

Note: Method A--no nutrient medium, method B--with nutrient medium.
*Composition containing organotin biocide as an additive.
**control samples of coatings based on compositions of organotin copolymers and polystyrene.
***Control sample containing no organotin biocide.



Samples of coatings after testing for fungicidal activity

Tin content (mass%):

а) 0.0001 *б*) 0.001 *в*) 0.01 *г*) 0.1 *д*) 0.1 (polystyrene composition) *е*) 2 *ж*) 0 (control)

According to the submitted data, synthetic polymers Nos 1-4 (see Table) show high efficacy when there is 10^{2}-10^{3} less tin than is traditionally used (0.5-1.0 mass%) [2].

Organotin polymers Nos 1-4 (see Table) dissolve well in most organic solvents. Varnish produced on their basis can be applied to the surface to be protected with a brush, roller, air or airless spray gun. The coatings consist of transparent fil with good ahesiveness (scored at no more than 1) to metal, plastic, glass and wood. Impact strength (direct and rebound) of coatings according to metal constitutes 20-50 kgf cm. Elasticity is 1 mm.

The synthesized organotin polymers are new, highly effective bioresistant materials. Coatings made on their basis not only protect against biodestruction various systems exposed to the deleterious effect of fungi, but are sterilizing, which is particularly important for manned pressurized areas.

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COMBINED EFFECTS OF STRESSORS ON THE LEVEL OF SPINAL REFLEX ARC STRUCTURES

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[Article by F. I. Furduy, S. Kh. Khaydarliu and L. M. Mamalyga]

[Text] Long-term restriction of motor activity alters appreciably the motor analyzer, including the spinal reflex arc which is the peripheral element of the central nervous system in effecting interaction between the body and environment [3, 12, 13]. The initial period of hypokinesia differs appreciably from the subsequent period of adaptation and is associated in animals with the "release" reaction and occurs in the presence of a marked stress reaction leading to stressed function of the central nervous system and most other systems of the body [1, 8]. Hypoxia is the most frequent companion of hypokinesia, as well as many other extreme environmental factors. However, there are virtually no data concerning the combined effects of various stressors on the level of the spinal reflex arc.

Our objective here was to study the morphological and cytochemical changes in cellular structures of spinal cord ganglia (SCG) and motoneurons of the ventrolateral nucleus (VLN) of the spinal cord on the level of the lumbar and cervical spine under the separate and combined effect of stressors (hypokinesia of differing duration and hypoxia).

Methods

Experiments were performed on standard albino male Wistar rats weighing 160-180 g. The rats were put in box-cages matched to their size. More rigorous restriction of motor activity (immobilization) in the 1st group of rats was obtained by securing (for 14 h) the legs, head, trunk and tail to special screens. The next 2 groups of animals were submitted to hypokinesia and immobilization for 13 h and, in this condition, they were "lifted" to an "altitude" of 8200 m in a pressure chamber, for 1 h. Finally, a group of intact animals was also submitted to hypoxia at the same "altitude" for 1 h. We used six animals in each series of experiments.

Upon termination of the experiments, the rats were decapitated, the lumbar and cervical intumescentiae together with the corresponding spinal ganglia were excised under refrigeration and fixed in cooled Brodskiy fixative. The methods of cytochemical analysis of RNA, as well as total and basic proteins,

and morphometric studies were described previously [5]. The digital material was submitted to statistical processing according to Student and Fisher.

Results and Discussion

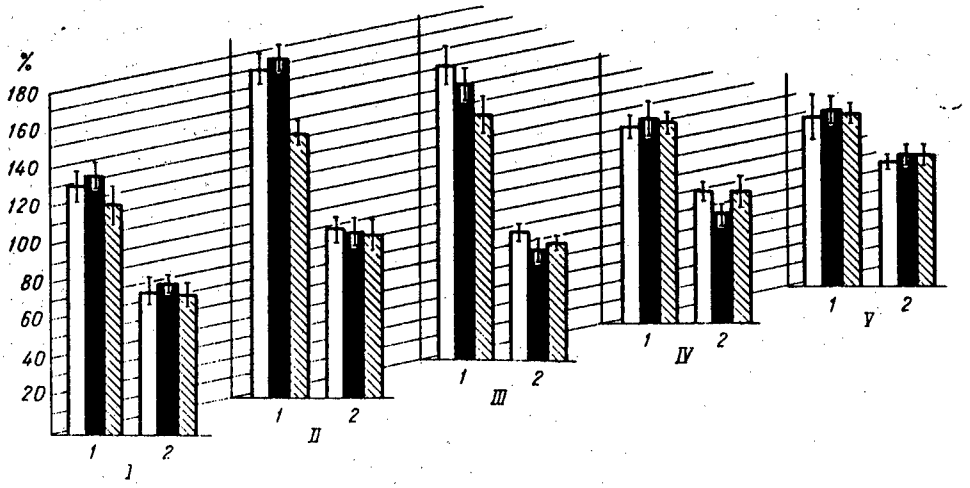
As we know, the early stage of restricted motor activity elicits a stress reaction, the severity of which depends on restriction conditions [1, 4, 5]. For this reason, we tested the effect of hypoxia on animals immobilized for 13 h, which had by that time reached a peak stress reaction, according to data in the literature [7-11], since this is the period when a phase of maximum increase in corticosteroid content of blood and brain tissue was demonstrable. Animals submitted for 13 h to less stringent limitation of mobility (hypokinesia) were exposed to the same factor.

The results indicate that the stress reaction induced by limiting mobility has a substantial effect on RNA and protein content of VLN motoneurons in both the lumbar and cervical segments of the spinal cord. Immobilization stress led to drastic increase in volume of VLN motoneuron cytoplasm in the lumbar region (by 29%) and increase in its RNA content, as well as in total and basic proteins (by 74, 80 and 60%, respectively), whereas under the effect of hypokinesia-induced stress no statistically reliable changes in these parameters were demonstrated (see Figure and Table). The opposite findings were made in analogous structures of the cervical region. Statistically reliable changes in levels of tested components (29% decline of RNA, 42 and 29% decrease in total and basic proteins, respectively) were found only with exposure to hypokinesia. Motoneuron cytoplasm volume decreased by 25%. Immobilization was also associated with a decrease in volume of cell structures of the cervical segment of the spinal cord (by 20%).

Volume of neuronal cytoplasm (μm^3) in different spinal cord segments of intact and experimental animals

Factor	VLN		SCG	
	lumbar spin.cord	cervical spin.cord	lumbar spin.cord	cervical spinal cord
Control	26 009 ±1650	11 736 ±161	30 390±965	33 123±1 277
Immobilization	33 539±1677*	9 571 ±136**	37 850±1 823*	30 581±665
Immobilization under hypoxic conditions	28 723±2134	8 231±208**	36 127±1 619*	34 082±1388
Hypokinesia	25 840±2508	8 808±421***	34 965±1 415	27 367±5921*
Hypokinesia under hypoxic conditions	22 607±1885	8 974±411***	29 5i2±2 064	35 131±1029
Hypoxia	32 934±477*	10 400±395*	36 019±1 583*	38 997±643i*

* $P<0,05$,
** $P<0,001$,
*** $P<0,01$,
i* $P<0,02$.



RNA content (white bars), total (black) and basic (striped) proteins in motoneurons of VLN in lumbar (1) and cervical (2) segments of spinal cord with exposure to hypoxia (I), immobilization (II), combination of immobilization and hypoxia (III), hypokinesia (IV) and hypokinesia combined with hypoxia (V)

The obtained data indicate that stress caused by immobilization and hypokinesia has a dissimilar effect on efferent structures of the spinal reflex arc that are on different levels of the spinal cord. And if the body is in a state of maximum stress (which is the case with immobilization), exposure to hypoxic stress attenuates the effect demonstrated with immobilization stress in VLN motoneurons of the lumbar region. In those of the cervical region, hypoxia drastically intensifies the changes found with immobilization. Thus, the combined effect of these factors led to marked decline in volume of motoneuron cytoplasm in the cervical segment of the spinal cord (by 30%) and in RNA, total and basic protein levels in it (by 32, 42 and 38%, respectively).

Cellular structures of SCG on the level of the lumbar region of the spinal cord reacted similarly to separate and combined exposure to immobilization and hypoxia. Similar findings were made for SCG neurons on the level of the cervical region.

Stress elicited by less rigid restriction of motor activity (hypokinesia) did not lead to statistically reliable changes in levels of RNA and proteins in VLN motoneurons of the lumbar segment of the spinal cord, whereas in the cervical region the decline in volume of motoneuron cytoplasm (by 26%) was associated with marked decline of RNA, total and basic proteins (by 29, 42 and 29%, respectively) (see Figure and Table).

Hypoxia in the presence of 13-h hypokinesia "erased" the effect that had occurred in VLN motoneurons of the lumbar region with hypoxia alone. In the cervical region, separate and combined exposure to hypokinesia and hypoxia led to similar changes in RNA and protein content.

Separate and combined exposure to the extreme factors led to about the same effects in efferent structures on the level of the lumbar and cervical segments of the spinal cord: statistically reliable changes were not demonstrable in RNA and protein content.

Thus, the marked decline of RNA and protein content of motoneurons in the cervical region of the spinal cord with exposure to stress factors separately or in combination indicates that the structures of this region are more affected than those of the lumbar region. This could be related both to the load on the cord segments studied and their morphofunctional distinctions.

As shown by the results of our studies, the motor neurons of the VLN of the lumbar and cervical segments of the spinal cord differ significantly in volume (28,620±1702 and 13,440±195 μm^3, respectively) in the control group of animals. The larger volume of neurons in the lumbar region is apparently attributable to the presence of longer processes, greater degree and specifics of tested functional loads on the hind limbs and on different muscle groups innervated by these parts of the spinal cord.

In the cervical segment of spinal cord VLN there are motoneurons that innervate respiratory muscles, which function more intensively in the presence of hypoxia and "release" reaction, which occurred in animals under stress caused by restriction of mobility.

The changes in volume of neuronal cytoplasm related to intensification of anabolism and catabolism of proteins and other intracellular chemical components, as well as hydration or dehydration of cells, were directly related to change in their RNA and protein content.

In addition, the decrease in RNA and protein content of some cells, demonstrated in most cases, is apparently related to changes in hormonal background, which occur under the influence of stress factors, rather than the specific effect of immobilization (or hypokinesia). Functional change in the adrenal cortex and hypophysis with brief restriction of motor activity, which led to drastic increase in adrenocorticotropic hormone and corticosteroid content of blood and nerve tissue [2, 6], could lead to intensified breakdown of the tested substances in cellular structures of the cord. Such a mechanism is confirmed by the findings of a number of researchers [14-16].

In our studies, hypoxia used in the presence of stress reactions elicited by different modes of restricting motor activity had a substantial influence on the ultimate effect in reactions of efferent structures only when it was present against the background of immobilization stress. However, hypoxia against the background of hypokinetic stress did not alter the effect that had occurred in motoneurons of VLN of the lumbar and cervical regions of the spinal cord.

There was no difference between the effects of single or combined factors on afferent structures.

Thus, our findings indicate that exposure to hypoxia in the presence of stress developing with different modes of restricting motor activity has an appreciable effect on levels of RNA and protein in efferent and afferent

structures on different levels of the spinal cord. The nature of changes in amounts of these substances depends on both the intensity of stress manifested prior to hypoxia and morphofunctional organization and metabolic distinctions of macromolecules in the cell structures studied.

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UDC: 613.693:92 Brestkin

MIKHAIL PAVLOVICH BRESTKIN (ON HIS NINETIETH BIRTHDAY)

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[Article by editorial board]

[Text] Mikhail Pavlovich Brestkin, recipient of the State Prize, professor and Major General of the Medical Service (retired), has celebrated his 90th birthday.

M. P. Brestkin was born on 22 April 1895 in the village of Makhrovka in Borisoglebskiy Uezd of Voronezh Province. In 1916, he enrolled in the Military Medical Academy. As a student at this academy, Mikhail Pavlovich displayed a leaning toward scientific research. After graduating from the academy he was a postgraduate student for 3 years in the Department of Normal Physiology under the guidance of Academician I. P. Pavlov and Professor V. V. Savich. Starting in December 1926, he worked for 20 years under the supervision of Academician L. A. Orbeli in the successive positions of junior instructor, instructor, senior instructor and deputy chief of the Department of Physiology of the Military Medical Academy.

In addition, M. P. Brestkin achieved well as chief of the Laboratory of Aviation Medicine founded in Moscow at the Institute of Aviation Medicine during the Great Patriotic War and in the immediate postwar period. From 1951 to 1952, he was chief of the Department of Normal Physiology and from 1952 to 1958, chief of the Department of Physiology of Military Labor, which he founded at the Military Medical Academy imeni S. M. Kirov.

M. P. Brestkin gained special renown as a scientist through his works (as well as those of his numerous disciples) dealing with investigation of the functional patterns of the body when exposed to altered environmental conditions. In these works, attention was focused on studies of the effects on animals of high and low pressure of both ordinary atmosphere and with altered gas composition. For these studies, a pressure laboratory was founded in the Department of Physiology of the Military Medical Academy imeni S. M. Kirov in the prewar years, which was outfitted with pressure chambers built by special orders, which permitted simulation of deep-water dives and high-altitude ascents with an eye on the future.

The scientific associates of this pressure laboratory, as well as other departments of the academy established, under the supervision of Academician

L. A. Orbeli and Prof M. P. Brestkin, several new scientific patterns and facts related to the effects of high and low partial pressure of oxygen, nitrogen, helium and carbon dioxide, the influence of decompression and compression pressure gradients, etc. The results of this work served as the basis of many preventive measures to assure safety of flights and deep dives, including those to record altitudes and depths for those times. In particular, together with A. A. Sergeyev and other researchers, M. P. Brestkin conducted studies that served as the basis for medical support of flight safety of stratonauts, P. Fedoseyenko, A. Vasenko and I. Usyskin who ascended in 1934 to the unprecedented altitude of 22,000 m in the Osoaviakhim stratosphere balloon. In the prewar years, a new method of deep diving was developed, which was based on replacement of nitrogen with helium in breathing gas mixtures, which made it possible to overcome the barrier of narcotic effect of nitrogen.

Investigation of the effects of accelerations and related G forces, including impact accelerations, was an important direction pursued by M. P. Brestkin and his disciples. On the basis of the results of these studies, measures were elaborated that attenuated adverse effects; the range of tolerance to impact accelerations was determined and a method was developed for rescuing flight crews by ejection. The work of M. P. Brestkin and bis disciples is characterized by the desire to find common functional patterns in the body under altered ambient conditions. They obtained numerous data that explained the mechanisms of reactions aimed at balancing the effects of unique factors on animals from the standpoint of evolutionary physiology, which enriched it significantly. The facts accumulated, their systematization and generalization served as the basis for M. P. Brestkin to develop a special discipline, physiology of military work. A total of 43 candidatorial and doctoral dissertations were prepared and defended under his supervision.

The scientific and pedagogic activities of M. P. Brestkin were highly rated by the Soviet government and recognized by the scientific community. He was awarded four orders and many medals. In 1951, Mikhail Pavlovich was elected member of the board of the Leningrad Society of Physiologists, Biochemists and Pharmacologists imeni I. M. Sechenov and in 1957, as chairman of the biomedical section of the Leningrad House of Scientists imeni M. Gor'kiy.

The cause to which M. P. Brestkin devoted the best years of his life is being continued by his numerous disciples who wish him good health and much success in his creative endeavors.

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